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THE TELEGRAPHIC JOURNAL AND
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SEP 21 1886

LIGHTHOUSE ILLUMINANTS.

Sir James N. Douglass, this year's President of the Mechanical Science Section of the British Association, chose as the subject of his address the development of lighthouses, light vessels, buoys and beacons, together with their mechanical and optical apparatus. During the last century a very considerable increase has occurred in the number of lighthouses and light-vessels on the various coasts of the world, and at the present time the number does not fall far short of 4,000; concurrently with the enormous increase in the number of coast lights during the last 50 years, very great improvements have been effected from time to time in their efficiency.

In 1857 a trial of the electric light, at the suggestion of Faraday, was made by the Trinity House at Blackwall, with a result so full of promise that a practical experiment was made during the following year. It was then at the South Foreland High Lighthouse, on December 8th, 1858, that the first important application of the electric arc light, as a rival to oil and gas for coast lighting, was made with a pair of Holmes's machines. The next year these trials were discontinued, but the results obtained were sufficiently encouraging to lead to the permanent installation of electricity at Dungeness Lighthouse in 1862. In 1863 the arc light was adopted by the French authorities at Cape La Hêve.

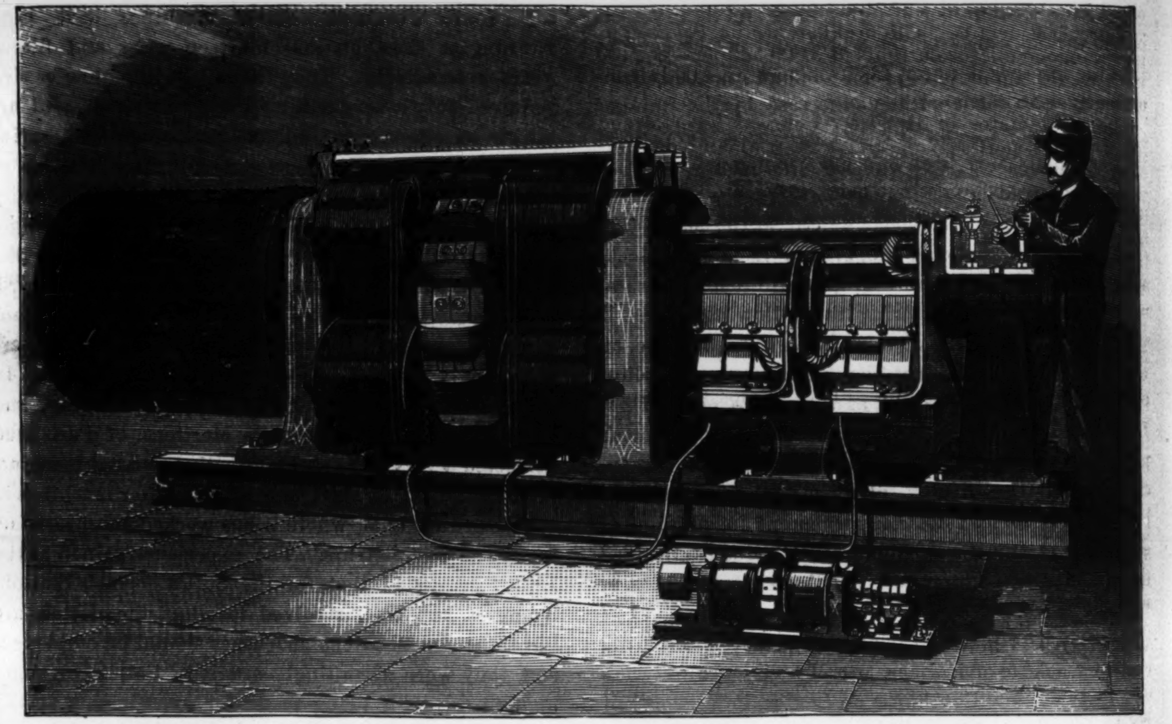
In 1871, after practical trials with a new alternating current machine of Holmes, two of such machines were supplied to a new lighthouse on Souter Point, coast of Durham, and in the following year the electric arc light, with these machines, was established in both the High and Low Lighthouses at the South Foreland, where it still shines successfully. The early experience with the electric light at Dungeness was far from encouraging. Frequent extinctions of the light occurred from various causes connected with the machinery and apparatus, and the oil light had, at such times, to be substituted. As no advantage can counterbalance the want of certainty in signals for the guidance of the mariner, no further step in the development of the electric light was taken by the Trinity House until the latter part of 1866, when favourable reports were received from the French lighthouse authorities of the working of the Alliance Company's system at the two lighthouses of Cape La Hêve. Complaints were also received from mariners, in the locality of Dungeness, of the dazzling effect on the eyes when navigating, as they are there frequently required to do, close in shore, thus being prevented from rightly judging their distance from this low and dangerous point. Therefore, in 1874, the electric light was removed from Dungeness, and a powerful oil light substituted. In 1877 the electric arc light was installed at the Lizard Lighthouses on the south coast of Cornwall, and arrangements are now being made for establishing it at St. Catherine's Lighthouse, Isle of Wight, and at the High Tower, on the Isle of May, Frith of Forth. The first machines of Holmes at the South Foreland were direct current, the machines provided by him for Dungeness being also of the same type. The French lighthouse authorities, however, adopted for their lighthouses at Cape La Hêve the "Alliance" alternating current magneto-electric machines, and, in consequence of the less wear and tear of those machines with greater reliability through their having no commutator, Holmes was required to supply alternating current machines for Souter Point and South Foreland. Those machines have been running at these stations fourteen years and fifteen years respectively. They have during this period required only a very trifling amount of repair, and are still in excellent order, but the time must soon arrive for replacing them by more powerful machines.

In 1876 a series of trials was made by the Trinity House at the South Foreland, with various dynamo-electric machines, for the purpose of ascertaining the then most suitable machine for adoption at the Lizard. The results were decidedly in favour of the Siemens direct current machine, and machines of this type were accordingly installed at the Lizard Station in 1878. In consequence of irregularities in their working, and because, at the time, Baron de Meritens, of Paris, had perfected a very powerful alternating current machine, it was resolved to send one of the latter machines to the Lizard for trial, where it has worked most satisfactorily for several years. The experience gained at the Lizard suggested that, for the St. Catherine's Station, where it had been resolved to adopt the electric arc light, the De Meritens machines should be employed, and they were accordingly ordered; but, as arrangements were then being made for experiments at the South Foreland for testing the relative merits of electricity, gas, and oil as lighthouse illuminants, it was determined that these machines should first be sent there for the experiments. Neither oil nor electricity has yet been successfully applied to the lighting of buoys, but Sir James Douglass thinks there now appears to be no reason why electricity from storage batteries should not be found efficient for the purpose at a reasonable cost. In 1884 an iron beacon, lighted by an incandescent lamp and the current from a secondary battery, was erected on a tidal rock near Cadiz. Contact is made and broken by a small clock, which runs for 28 days and causes the light to show a flash of five seconds, followed by a total eclipse of 25 seconds. The clock is also arranged for eclipsing the light between sunrise and sunset. The apparatus is the invention of Don Isas Lavaden.

In 1881 it was considered by the lighthouse authorities of this country that the time had arrived when it was absolutely necessary that an exhaustive series of experimental trials should be made, on a practical scale, for the exact determination of the relative merits (both as regards efficiency and economy) of the three lighthouse illuminants, electricity, gas, and mineral oil, which, by the process of natural selection, may be regarded as the fittest of all those at present known to science. After many unforeseen difficulties had been overcome, this question of universal importance was, in July 1883, referred by the Board of Trade to the Trinity House, who accepted the responsibility of carrying out the investigation.

These investigations were carried out in full view of all who were in any way interested in the subject.

In order to obtain, with uniformity and method, a concensus of comparative eye-measurements—in addition to the measurements of the Committee and their officers at their different stations ashore and afloat, to those of the coastguard men at nine stations between Dungeness and the North Foreland, and to the more precise scientific measurements of the experts—special observation books were prepared and widely distributed to shipping associations and port authorities, with a view to their securing the co-operation of masters of vessels, pilots, and others navigating in the vicinity of the South Foreland.



The South Foreland Station is especially adapted for lighthouse experiments generally, because of the existing facilities for observations on land and sea. The land in the neighbourhood has no hedges and few trees, and affords facilities for observations at distances of between two and three miles. The station is provided with surplus steam power for driving experimental machines for electric lights, and it is easily accessible from London.

During a period of over twelve months the experimental lights were exhibited, and watched by numerous observers, trained and untrained, scientific and practical. During that period a vast amount of valuable evidence was collected; by the aid of which the Committee were subsequently enabled to state their conclusions with definiteness.

The final conclusion of the Committee on the relative merits of electricity, gas, and oil as lighthouse illuminants is given in the following words:—"That, for ordinary necessities of lighthouse illumination, mineral oil is the most suitable and economical illuminant, and that for salient headlands, important landfalls, and places where a very powerful light is required, electricity offers the greatest advantages."

A perusal of Sir James Douglass's excellent and instructive address leads us to the belief that there is a great field for the use of dynamo-electric machinery in illuminating important lighthouses, and that this will form an industry of no inconsiderable dimensions in the future.

BRUSH'S COLOSSAL DYNAMO.

THE accompanying cut, writes Mr. H. C. Hovey in the *Scientific American*, represents the smallest and the largest dynamos thus far manufactured by the Brush Electric Company, of Cleveland, Ohio. Before proceeding to describe the latter, it may be of interest to mention the facts concerning the original dynamo produced by this inventor.

It is related that about nine years ago Mr. Charles F. Brush, then a professional chemist in the city of Cleveland, intimated to his friend, G. W. Stockley, at that time President of the Telegraph Supply Company in the same city, his purpose to make a dynamo that should excel the French and German machines. Without further ado, Mr. Brush completed his dynamo in about two months, brought it to the factory, set it to work, and found it to work successfully on the very first trial. It was purchased by other parties, and has been running constantly ever since without needing repairs. This illustrates the quietness and thoroughness with which this distinguished inventor works. A peculiarity of his method is that he wholly discards empirical experiments; but when he sees that some new machine is demanded, he proceeds to meet the demand.

In this he is greatly aided by his remarkable powers of vision. He will draw his original designs, send them to the pattern maker, and when the model is returned will, by his unassisted eye, detect any deviation to within the sixty-fifth part of an inch. He can also, it is said, subdivide an inch into hundredths, using only a common pocket ruler, and do it so accurately that on testing his work by the vernier it shall be found correct to within two one-thousandths of an inch.

Last spring Mr. Brush contracted with the Cowles Electric Smelting Company (then of Cleveland, but now removed to Lockport, N.Y.), to build and deliver a 500 horse-power dynamo within three months, under forfeit. He made no model nor experimental machinery, although the mechanical design was new, as may be seen by the cut, and the electrical proportions had to be worked out entirely *de novo.* He simply made his working drawings and placed them in the hands of Mr. Possons, the company's superintendent. The patterns, of course, had all to be made new. The machine was built exactly according to the original drawings; its parts were duly assembled; it was set in place and tested for ten days with a 500 horse-power engine under all varying conditions of load, and it was found to realise all expectations, not only in the output of current, but in all mechanical and electrical details. The problem of the commutating arrangements for currents of 3,800 ampères at 100 volts would alone have been enough to discourage ordinary electricians.

The commutator of Brush's "Colossus" performed its functions perfectly on the first trial, and no difficulty whatever was experienced in this respect. In order to avoid attacking this very problem, Mr. Gordon, in making his great dynamo, was obliged to make the field magnets revolve, the armature remaining stationary. Gordon's dynamo, built several years ago in England, was the bulkiest machine of the kind ever constructed, being two or three times as heavy as Brush's "Colossus." It had nearly as great electrical capacity, but did not work for any great length of time, when, as we understand, it went all to pieces on account of mechanical imperfections. The "Colossus" represents the latest advance in dynamo building, having the greatest electrical capacity of any machine ever hitherto made—having, perhaps, five times the capacity of Edison's famous "Jumbo." Indeed, the Brush Company itself, a few years ago, would have had to build a dynamo of double the size to get the same capacity. But this dynamo embodies all Mr. Brush's latest improvements, and may safely be pronounced the foremost achievement of its kind.

The work to be required of it at the Cowles Smelting Works will be the reduction of refractory ores. This company has for some time past been using a Brush dynamo of 125 horse-power, and the results attained have been so remarkable as to justify the expectation of still more wonderful triumphs by the means now placed at their command. Precisely what these may be, however, is as yet a matter of conjecture.

Those already familiar with the dimensions and powers of other dynamos will be specially interested in the following data, given by Mr. Brush, concerning the "Colossus:"—The whole machine is 14 feet long, 5 feet 2 inches high, 4 feet 2 inches wide, and weighs in all 22,000 pounds. The weight of the copper wire used on the machine is 6,250 pounds. The diameter of the pulley is 40 inches, and of its face 45 inches. The normal speed of the dynamo is 430 revolutions per minute. The electrical capacity is 300,000 watts, or the equivalent of 5,000 incandescence lamps of 16-candle-power each. We show in the foreground of our picture the smallest sized dynamo made by the Brush Company. The appearance of the largest and smallest machines may be seen at a glance.

Edison Central Stations.—In America the Edison central station business now embraces fifty companies supplying light for about 160,000 glow lamps, and employing a capital of about 5½ million dollars. This large industry has been developed in less than 3½ years.

THE BRIGHT PLATINUM PLATING PROCESS.

SINCE the industrial application of Messrs. Elkington's discoveries relating to the electro-deposition of metals —gold, silver, copper, &c.—led to such great success, many attempts have been made with the view of applying a similar process to the electro-deposition or coating of baser metals with platinum.

It has been known for many years that platinum, while considerably less in market value than gold, has an equal if not greater power of resistance to exterior influences. Its surface once bright can never be touched or tarnished by any simple acid; and to all practical intents and purposes, the metal being much more dense and harder than gold, will resist a far greater measure of wear and tear than its more precious congener.

Hence, it long since became apparent to those interested in the maintenance of bright metallic surfaces, that the successful electro-deposition of platinum would be a most valuable acquisition to our industrial resources.

Many attempts to produce this end followed, but until lately they proved more or less abortive. It was found that although platinum was quite capable of being deposited electrolytically, the process was uncertain in its action; the deposited metal being black, pulverulent and non-adhesive to the surface upon which it was deposited. The three chief desirable objects of success were thus unobtained.

It is, therefore, satisfactory to note that during the last few months a method has been discovered by an ingenious English inventor by means of which platinum can in the first place be deposited upon any surface capable of receiving electro-depositions of other metals; in the second, that it can be thus deposited in a perfectly dense metallic or reguline condition, having a lustre equal to that of silver plate, and at the same time adhering firmly to the material upon which it is deposited.

The patent rights for Great Britain and foreign countries covering the above invention, have been acquired by the "Bright Platinum Plating Company, Limited," whose works are installed in London and fairly started in a good way of business.

The great industrial importance of this invention cannot be over-rated; its applications are innumerable.

Silver blackens and tarnishes upon the slightest exposure to an atmosphere or liquid containing compounds of sulphur. Platinum retains its perfect lustre under all such circumstances. Brass soon becomes discolcured and covered with verdigris, so also does bright copper, while steel, especially that used in the manufacture of the finer class of goods, rusts until the beauty or utility of the article is gone. Platinum never becomes discoloured, neither does it rust.

In the manufacture of acids and in the preparation of various articles of domestic consumption, the use of solid platinum, drawn or wrought, has been rendered necessary on account of the solvent action these acid liquors have upon other metals. The coat of platinum deposited by the process above alluded to, is, however, of such a dense form and so perfectly reguline, that a copper or iron vessel thus plated may replace that of solid platinum at one hundredth part of the cost.

As a proof of this, it may be stated that German silver spoons, which before plating with platinum would have dissolved like sugar in boiling nitric acid, have after submission to the coating operation, been boiled in the same acid for hours at a time, without being acted upon in the slightest degree.

It is evident that in the process cited above, something is indicated which ought to arrest the attention of intelligent manufacturers.

American Telephone Patents.—Prof. Gray denies flatly that he has been negotiating with the American Bell Company, which is represented as anxious thus to secure an extension of its monopoly for at least ten years.

THE BRITISH ASSOCIATION.

(*Specially Reported for the "Electrical Review."*)

MULTIPLEX TELEGRAPHY.

By WILLIAM HENRY PREECE, F.R.S.

TELEGRAPHIC business grows in England at such a pace that the demand for extra wires is constantly arising. Messages, which in August, 1870, averaged a total of 270,000 per week, now, under the influence of a cheap and convenient tariff of one halfpenny per word, have reached a total of 1,034,000. The demand for increased capacity for the transmission of messages has been largely met by improvement in apparatus and by new systems of working. The rate at which a telegraphist can manipulate a key is, of course, limited. An experienced hand can send or receive 40 words per minute, but 450 words are frequently sent by automatic apparatus; while the quadruplex apparatus enables four telegraphists to work one wire at the same time, or, in other words, four messages can simultaneously be sent over one wire.

A new system has recently been imported from America which still further increases the capacity of wires for the conveyance of messages. This is the system of Mr. Delany, which is based upon two main principles, first, that of synchronism, or the simultaneous motion of similar pieces of apparatus at two different places; and secondly, that of distributing to several telegraphists the use of a wire for very short equal periods of time, so that practically each telegraphist has the line to himself during these periods.

The combination of these two principles has been much experimented upon on the Continent. It was introduced by Meyer in Vienna in 1873, and it has received considerable attention in France in the hands of M. Baudot, who exhibited it at the Paris Exhibition of 1881.

As Delany's system differs very markedly from what are known as the duplex and quadruplex systems, it is proposed for clearer definition to give to the modes of working his system names based on the Greek word *hodos*, a way.

Thus a two way mode of working, or a mode by which two messages are practically sent at the same time, will be *diode* working, three way *triode*, four way *tetrode*, five way *penthode*, and six way *hexode*.

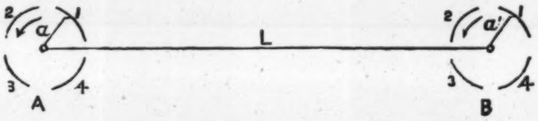


FIG. 1.

Duplex and quadruplex are such well rooted and explicit terms defining particular modes of working by compensation, that their application to different modes of working based on a different idea may lead to confusion, while new and distinct terms will confine the attention to the new and distinct system.

A and B (fig. 1) are two separate offices connected together by a line wire, L.

If the arms *a* and *a'*, in electrical connection with the line wire L at A and B, rotate simultaneously around the circles 1, 2, 3, 4, in the direction of the arrows, making contact upon the segments as they pass, then when *a* is at A 1 *a'* will be at B 1, when *a* is at A 2 *a'* will be at B 2, and similarly for 3 and 4.

If 1, 2, 3 and 4 at each office be each in connection with a set of similar telegraphic apparatus, the four sets at one office will be in direct communication with the four sets at the other office as the arms *a a'* touch their corresponding segments. Thus for each rotation of the arms the instruments at A 1 and B 1, will be in direct communication with each other *once;* and so on with those at A 2 and B 2, &c.

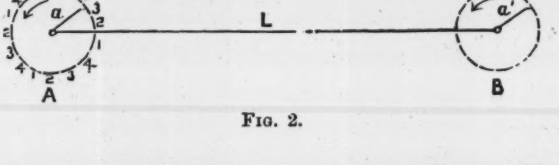


FIG. 2.

If each segment be divided into four segments (fig. 2), and by means of these be connected with the four instruments instead of with only one of them, then during one complete rotation each arm will place corresponding instruments in communication with each other *four* times. Or if each circle be divided into 40 segments and each of these 40 into four segments, then corresponding instruments will be in communication with each other *forty* times during each complete rotation of the arms "*a*" and "*a'*".

In Delany's apparatus there are 84 segments in the whole circle, and these are grouped differently according to the number of ways of working. Hexode working requires one grouping, triode another, diode another, and so on.

Two tuning forks pitched to absolutely the same note, and set in vibration by currents like an electric trembling bell, will move in synchronism, but the synchronism cannot be maintained. The deposition of dirt, dust, or moisture, changes of temperature, variation of current, produce changes which affect the rate of motion.

Delany has adopted a reed instead of a turning fork. On one side of the reed is placed the contact for keeping it in vibration, and on the opposite side there is another contact for transmitting the vibrations into the electro-magnets of the motor, thus keeping it revolving in unison with the vibration of the reed.

For Hexode working the circle is divided into six groups (fig. 3), the groups being separated by the correcting segments.

The segments are not only insulated from each other, but are separated by the spokes of a brass wheel. Each group of 12 segments is further subdivided into two sub-groups of six, in which the corresponding segments are connected, so that 1 and 1, 2 and 2, 3 and 3, and so on are electrically joined together. Not only so, but they are connected to every corresponding number in the other groups around the circle.

The twelve segments numbered 1, are electrically connected to the telegraphic instrument numbered 1; the twelve segments numbered 2 are connected to the instrument numbered 2; and so on. The first, third, and fifth segments are connected together, as also are the second, fourth, and sixth, but the first three are intended to *receive* currents from the distant station, while the second three are connected to a battery, B, and so can *send* currents to the distant station.

The correcting segments are connected in this manner for lines whose inductive capacity is small, and where the retardative effect on the current is consequently slight, but the space allotted to the correcting segments is always equal to that of two of the ordinary segments so that when the capacity of a line is considerable and coupling up the segments has to be resorted to to admit of the reception of a signal which is retarded and which arrives a segment late it is always possible to provide in a similar manner for the correction. The correcting portions of the distributor are practically two circuits.

The arm or trailer passes lightly on the surface, and moves continuously round the circle, coming successively in contact with every segment. It moves in the opposite direction to that of the hands of a watch. It is electrically connected to the line wire. In every rotation it makes 84 electrical contacts, 72 of which are for telegraphing, while the others are for maintaining synchronism.

The function of the trailer is to place the line wire successively in connection with the segments in the different groups. The currents of electricity that flow through the line wire are dependent upon the operations performed upon the telegraphic apparatus, and they are broken up into short rapid pulsations or impulses by the momentary contacts made by the trailer.

Delany uses the La Cour wheel in connection with his actuating, correcting, and synchronising devices.

An iron toothed wheel is placed before the poles of an electro-magnet which is magnetised periodically and regularly by currents from a local battery, the currents being sent at each vibration of the reed.

The end of the reed vibrates between the extended pole pieces of an electro-magnet and thus it vibrates for synchronising purposes in an intermittent magnetic field. The electro-magnet is excited by means of a local battery whenever the line correcting relay is actuated by a correcting current from the opposite end. When the magnet is excited the magnetic field in which the iron reed vibrates tends to retard its rate of vibration by attraction so that if it vibrates too frequently its rate is checked. The normal rate of vibration may be adjusted by a sliding weight, or in various other ways not shown in the figure.

There is nothing peculiar in the telegraphic apparatus (the usual Morse sounder set), except the relay which by its form is rendered sluggish so that the sharp rapid currents collected by the trailer are practically made continuous in their action on the armature of the relay. The currents flowing through the line wire are short, sharp, rapid impulses or waves of electricity, and to convert these waves into telegraphic symbols, such as Morse characters, some mode is needed to render them continuous for the duration of a dot or a dash. The relay has a condenser and a permanent horseshoe magnet, N, S, fixed below the coils. The cores are thus polarised. The result is that the self-induction of the coils, adjusted by the condenser, retards the demagnetisation of the core, so that the effect of the rapid succession of short currents is made continuous upon the armature of the relay, and the marks are made as though they were produced by continuous currents.

The currents received from the line were formerly in a direction to break a local circuit which allowed the armature of an intermediate relay to rise and thus complete the circuit of the receiving sounder.

This arrangement was introduced because the ordinary method of completing the local circuit was too slow and the contacts were not firm enough.

When the distributors are running correctly, the trailer at the receiving end will be on an insulated segment, and the current will therefore not pass into the correcting relay, but if the trailer be the slightest in advance of that sending the correction, the current will actuate the correcting relay which in its turn will excite the correcting magnet at the end of the reed, and thus momentarily retard its rate of vibration.

Perfect synchronism is again obtained, and the correcting currents cease to flow. Six correcting currents can be sent at each revolution, three in one direction and three in the other. Thus a deviation of a thousandth of an inch can be speedily rectified.

This method of Mr. Delany is perfectly automatic in its action, and it maintains synchronism to an extent that has never before been known. Attempts have been made to synchronise by sending correcting currents in one direction and applying the corrections mechanically to moving parts. Baudot brings to bear a friction break by such means, but it has not been successful in practice, whereas Delany's method is practical and successful.

The "distributor" rotates nearly three times in one second, hence 252 contacts are made each second in hexode working. The distance to which the system can be worked hexode is limited, for owing to the retarding effect of static induction the number of currents which can be sent per second is limited by the static capacity of the line. Now as the static capacity of the line has the effect of retarding the speed of the current, it follows that the limit of working is dependent on the magnitude of the static capacity, for if the current be late it will enter the wrong segments, and confusion of signals will result.

The retarding effect of static capacity can be met by making each group of a greater number of segments, or by making the segments of greater breadth, but this has the effect of reducing the number of ways of working. Either plan would reduce the hexode to tetrode or triode working.

So far, it should be understood, the system has been described as one for working in either direction (not simultaneously as in duplex, but alternately), as in ordinary simplex working. If, however, it be regarded as a system for working in one direction, distance has not the same effect upon it.

If static capacity only so reduces the speed of the current that while it leaves segments 1 at station A, it enters segments 2 at station B, then it is possible still to work five ways in *one direction*, for every other segment will be advanced one. For this mode of working two wires are necessary, one for sending and the other for receiving, but it has this advantage, that two wires can be converted into ten circuits. Segment 6 is rendered useless in consequence of its currents arriving at B when the trailer is on the correcting segments. Working in either direction, hexode is feasible between London and Brighton, but tetrode is the limit to Bristol and Manchester. In one direction, however, to Bristol and Manchester, even six circuits have been operated, so that with two wires 12 circuits might be worked, six in each direction.

When the system was taken up by the Post Office the adjustments of the relays had to be very carefully made, and very light flexible spiral springs were necessary in order to adjust finely, and even then the signals would occasionally break up. The distributor has undergone modification to suit the retardation of certain wires, and to prevent bridging and consequent sparking as the trailer passes over the segments.

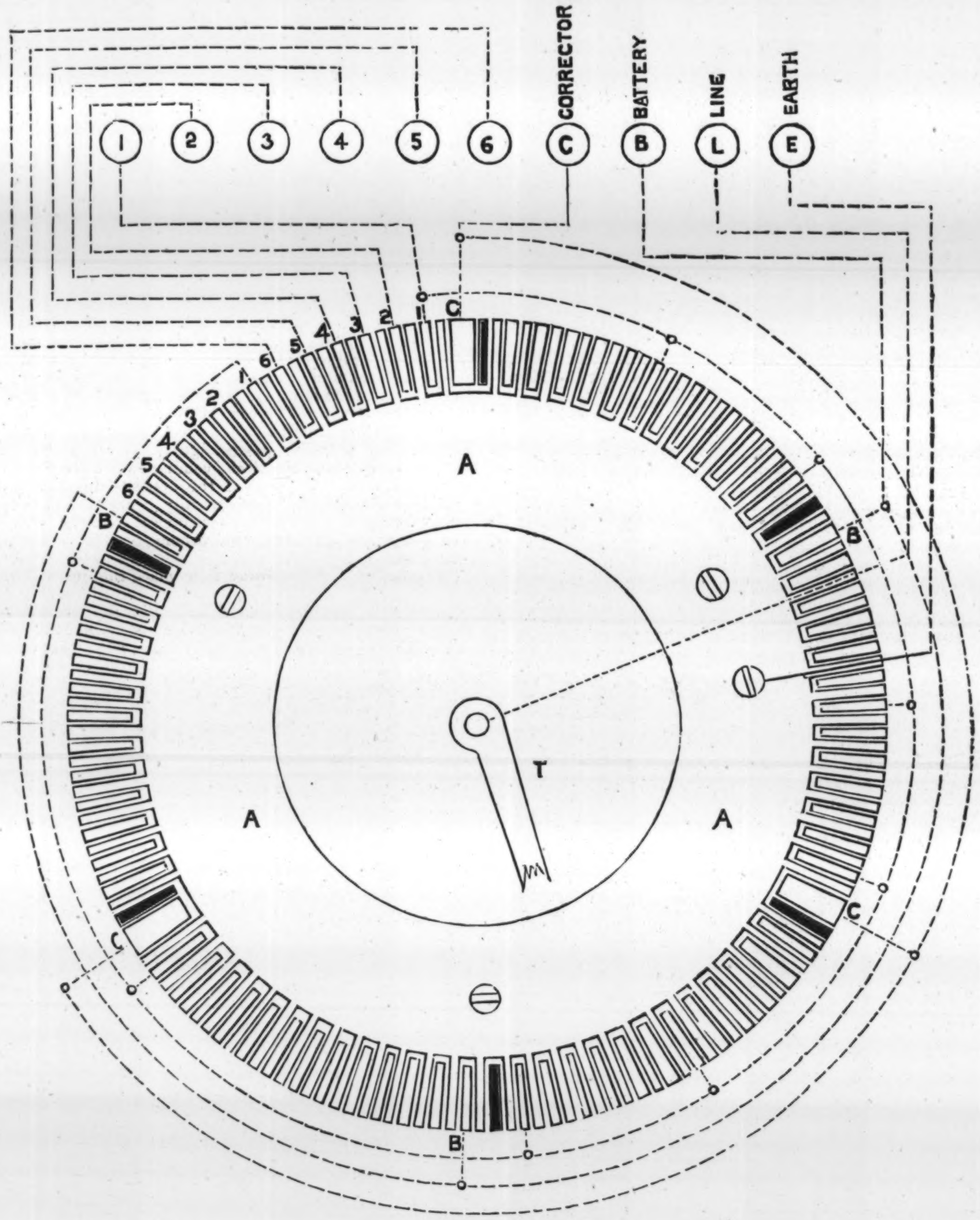


FIG. 3.

When making experiments between London and Manchester, it was found that the retardation caused the current to be received about $\frac{9}{10}$ths of a segment late, and that, as the trailer immediately passed on to the earth segment, some of the current was lost.

In order to remedy this defect, every alternate earth segment was removed from the earth plate and fixed to a separate ring of ebonite outside the original circle. These segments are used for each circuit.

A switch is attached to the sending key for connecting the detached middle segment to the segment to the right of it for receiving, and at the same time to put the left hand segment to earth to prevent any surplus discharge from the preceding circuit passing through the relay and mutilating the signals. When the switch is in position to "send" the detached middle segment is then disconnected, and the segment to the right of it is put to earth to discharge the line after sending a current.

The signals are, of course, still received into the line relay from the respective groups of segments belonging to a particular arm; but, instead of the armature of the line relay breaking the local circuit of an intermediate sounder or relay, which in turn completed the local circuit of the receiving sounder, the latter sounder is now worked direct from the tongue of the relay by completing the local circuit in the ordinary way. This simplification is effected by means of a large form of polarised relay, the intermediate sounder is entirely got rid of, and there is nearly the same margin of adjustment as in the case of ordinary circuits.

There was formerly much difficulty in starting the motor owing to the presence of a shunt across the contact points to take the spark. Small condensers have been substituted for these spark coils, and they are placed directly on the coils of the electro-magnets. Starting the motor is now an easy operation, and the driving battery is not exhausted so quickly.

The circuits are worked on the double current system by dividing the battery originally used so that the potential is reduced to about one half of that previously in use with the original system. This, of course, is important, as affecting the life of the underground wire.

The traffic capacity is 50 messages per arm per hour.

The great advantage of the system is that it does not disturb the general mode of working adopted in this country. The sounder system is retained. Key working is maintained. All initial delay due to punching is avoided. The skill of able telegraphists is fully utilised. Each telegraphist has an independent circuit, so that he has not to wait for a lagging co-operator as in quadruplex. When there is a rush of traffic in one direction the system can be worked all in one direction, and not only half of it as in the quadruplex. The system, moreover, is only in its infancy, and there is little doubt that more extended experience will lead to further other improvements.

DISCUSSION.

Sir **WILLIAM THOMSON** said the method described by Mr. Preece was very old in principle, but its practical realisation was particularly beautiful. The general idea of telegraphing in that way was founded upon the principle that the telegraph wire was not occupied during more than a small part of the time that one operator was giving it work to do. One operator could scarcely make more than ten taps a second, and five or six per second was the ordinary rate of working. If all effects of a single tap passed out of the line in the one-hundredth part of a second, then $\frac{99}{100}$ths of the whole time the operator was working the line was at rest, and there might be 99 other operators taking note of the intervals of rest of the cable and giving it his work to do. That would be pushing the thing too far, but they now heard that it had been accomplished successfully by six operators. This method of operation occurred to him and he patented it in 1858. The patent was drawn for him by Prof. Rankin, who gave rather a curious illustration of the method. He showed that two messages might be sent over the wire simultaneously in this form:—PFRROETEETCRTAIDOEN. He (Sir William) took absolutely no credit for this invention. The gist of a thing of this kind was in its realisation. They had seen the wonderful way in which it had been realised by Delany, whose system was one of the most beautiful and practical systems of telegraphy.

Mr. **E. H. CARBUTT** asked Mr. Preece what the actual loss on an underground line was compared with overhead wires.

Mr. **PREECE** said the loss was practically the reduction of the speed of working. Between distant places, such as London and Glasgow, it meant that for every mile of underground wire inserted in the telegraph line on such a circuit, the capacity for transmitting one word per minute was lost, and that became a very serious item when they were dealing with a large number of messages. There was one important point in connection with the Delany system which he would like to mention. Its introduction into England was really due to the visit of the British Association to Canada in 1884. He (Mr. Preece) went over to Montreal, and in company with several others who were now present, went on to Philadelphia, where he found the Delany system at the Electrical Exhibition. The Americans were supposed to be a go-ahead people, but they did not seem to see much merit in the Delany system. He did, however; he saw it was just the thing that was wanted in England, and accordingly brought the inventor over to England, and tried the system at the Post Office, with the result that they secured its use for the duration of the patent, and sent the inventor back very happy indeed.

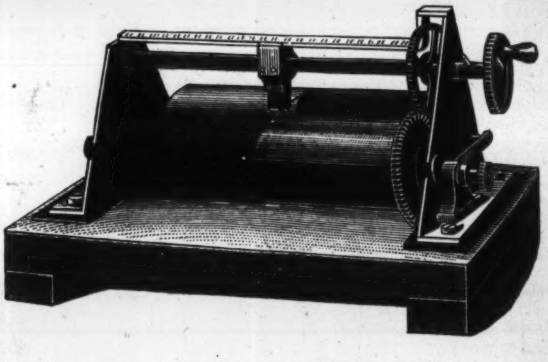
AN IMPROVED WHEATSTONE'S RHEOSTAT.

By Sir WILLIAM THOMSON.

(Section A.—Mathematical and Physical Science, Tuesday, September 7th.)

WHEATSTONE'S rheostat was invented over 40 years ago; but, though admirable in conception, and commonly shown on the lecture table in illustrating and explaining the nature of electric resistance, it is scarcely if at all used in the laboratory. This is altogether owing to practical defects in the instruments as commonly constructed. The wire comes loose, the contacts are uncertain, and, the current being incessantly broken and made again, the galvanometer needle is perpetually swinging about instead of showing a continuously increasing or diminishing deflection as the resistance is wound out of the circuit or wound into it.

Modifications of the original instrument have been made from time to time; and a very important improvement was recently introduced by Mr. Jolin, of Bristol. In Jolin's rheostat, a toothed wheel, fixed on one of the two cylinders, gears into a toothed wheel on a shaft carrying the other cylinder, and a spring fixed to this shaft acts on the last named cylinder, which surrounds it on the principle of the main-spring of a watch. By this arrangement the wire is kept tightly stretched, and the barrels can be turned both forwards and backwards by means of a handle attached to one of them; and the necessity of shifting the handle from one to the other when the motion is to be reversed is obviated.



In the improved rheostat the spiral groove in the non-conducting cylinder of previous instruments is dispensed with, and the wire is guided between the cylinders so as to be laid on them spirally by means of a travelling nut on a long screw. The screw is turned by the handle, and carries a toothed wheel, which gears into two toothed wheels, one of which turns one of the cylinders, and the other the aerial shaft of the other cylinder containing the watch spring. The guiding nut is also arranged to stop the motion of the screw shaft at each end of the range, and so prevent the possibilility of overwinding. It also carries an index which moves along a graduated scale and counts the turns of the wire on the insulating cylinder.

In Jolin's rheostat the two cylinders are geared together, as already described. The two cylinders are geared together directly, and turn in contrary directions, the wire passing from the upper side of one to the under side of the other. In the new instrument, as is seen in the diagram, the toothed wheels of the two cylinders are turned in the same direction by the wheel on the screw shaft, and the wire passes horizontally from the top of one cylinder to the top of the other.

The conducting cylinder and the wire are both of platinoid, a metallic alloy having properties which make it specially suitable for the purpose. It has very high electric resistance, very small temperature variation of resistance, and it remains with its surface almost or altogether untarnished in the air. On account of the last named property the contact between the wire and the conducting cylinder is as perfect as can be desired; and continuity of action, which was a great difficulty in the old form of the instrument, is absolutely complete.

ON A NEW FORM OF CURRENT WEIGHER FOR THE ABSOLUTE DETERMINATION OF THE STRENGTH OF AN ELECTRIC CURRENT.

By Prof. JAMES BLYTH.

(Section A.—Mathematical and Physical Science, Thursday, September 2nd.)

THE object of this paper is to describe a method of absolutely determining the strength of an electric current by measuring in grammes' weight the electro-magnetic force between two parallel circular circuits, each carrying the same current.

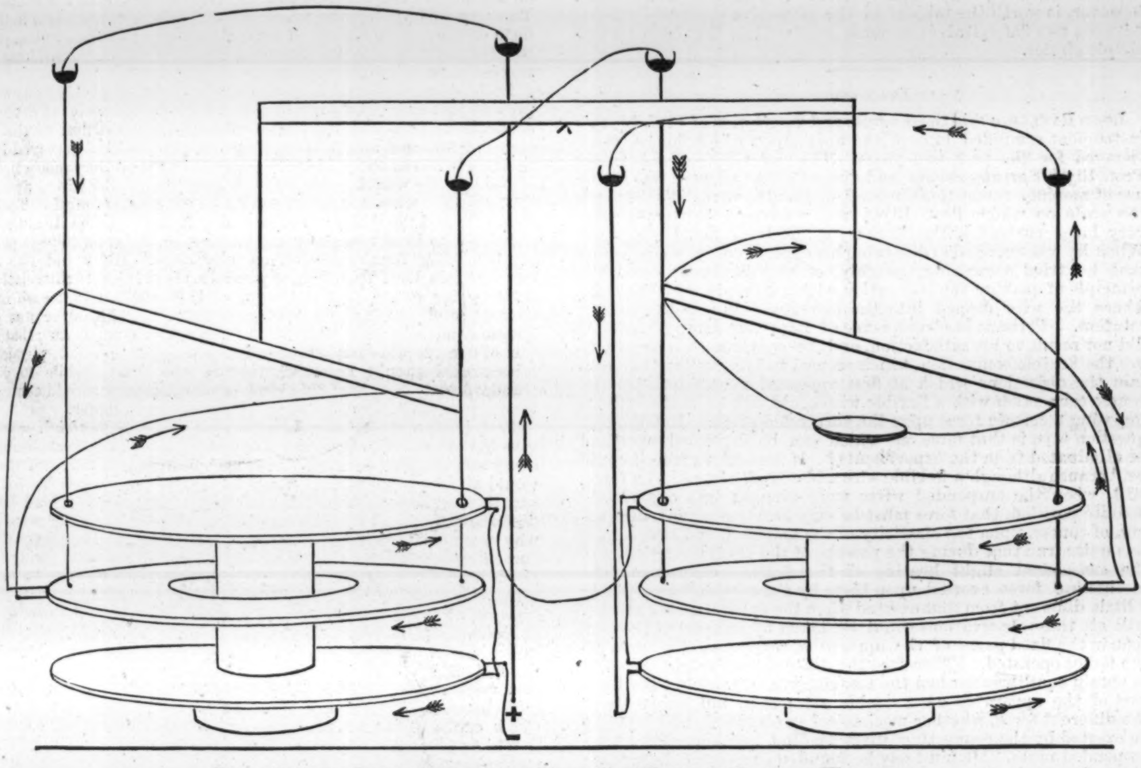
For convenience of calculation the circles have the same radius, and are placed with their planes horizontal.

The construction of the instrument is as follows:—A delicate chemical balance is provided, and the scale pans replaced by two suspended coils of wire. Each of these is made of a single turn of insulated copper wire (No. 16 about) fixed in a groove round the edge of an annular disc of glass or brass of suitable diameter. The disc is made as thin and light as possible consistently with perfect rigidity. By means of two vertical pillars of brass this annulus is attached to a rigid cross bar of dry wood or vulcanite, in the middle of which is placed a hook for suspending the whole from one end of the balance beam. On each side of the hook, and equally distant from it, two slender rods of brass are screwed into the wooden bar, which support two small platinum cups for holding mercury or dilute acid. The position of these cups is so adjusted that when the whole hangs freely the cups are in line with the terminal knife edge of the balance beam, and have their edges just slightly above its level. The free ends of the insulated wire surrounding the disc, after being firmly tied together for a considerable length and suitably bent, are soldered to the brass supports of the platinum cups, which thus serve as electrodes by means of which a current may be sent through the suspended coil. A precisely similar coil is suspended from the other end of the balance beam.

We now come to the arrangement by means of which a current is led through the suspended coils, so as to interfere as little as possible with the sensibility of the balance. This constitutes the essential peculiarity of the instrument, and is effected in the following way:—An insulated copper wire, having its ends tipped with short lengths of platinum, is run along the lower edge of the beam, and is firmly lashed to it by well rosined silk thread. The ends of this wire bent twice at right angles, are so placed that their platinum tips dip vertically into one of each pair of the platinum cups which are attached to the vertical rods of the suspended coils. From the other cup of each pair proceed two similarly tipped copper wires, which run along the upper edge of the beam, and are also firmly tied to it. These wires, however, only proceed as far as the middle of the beam, where they are bent, first outwards, one on each side of the beam, at right angles to it, and then downwards, so that the platinum tips are vertical. The latter dip into two platinum cups attached to two vertical rods, which spring from the base-board of the balance. These rods are placed at equal distances on each side of the beam, and are of such length that the platinum cups are in line with the central knife-edge of the beam, and have their edges just a little above its level. There are thus in all six cups and six dipping wires. Three of these are in line on one side of the beam, and three on the other. Also the line joining the points of each pair of dipping wires is made to coincide with the corresponding knife-edge; and, further, the edges of the cups are all in the same plane when the balance is in equilibrium.

From this it will be obvious that any motion of the beam in the act of weighing causes only a very slight motion of the platinum wires, which dip into the fluid contained in the cups. The resistance, due to the viscosity of the fluid, is thus very small, even in the case of mercury, and much smaller still when dilute acid is used. In point of fact, the diminution of sensibility due to this cause is less than in the case of determining the specific gravity of solids by weighing in water in the ordinary way. With clean mercury it is quite easy to weigh accurately to a milligramme.

The fixed coils, constituting two pairs, have the same diameter as the suspended coils, and, like them, are made of single turns of insulated wire wound round the edges of circular discs of glass or brass. The discs of each pair are fixed at the requisite distance apart to a cylindrical block of wood, so as to have their planes exactly parallel and their centres in the same straight line. To ensure this they are turned up and finished on the same cylindrical block on which they are finally to rest. When in position they are so placed that, when the balance is in equilibrium, each suspended coil hangs perfectly free to move with its plane horizontal and exactly midway between a pair of fixed coils. For this purpose, as will be seen, it is necessary that two large holes be drilled in the upper disc of each pair, so as to allow the brass pillars of the corresponding annular disc to pass freely through. When the connections are made, the current is led through the entire apparatus in such a way that, while the electro-magnetic force acting on the one suspended coil causes it to descend, the electro-magnetic force acting upon the other causes it to ascend. The total force tending to disturb the equilibrium of the balance is thus exactly four times that due to an equal current circulating in two parallel circles of the same diameter and with their planes at the same distance apart. The current strength is estimated from the number of grammes required to restore the balance to exact equilibrium, the weights being placed into small scale pans attached to the movable part of the apparatus.



DIAGRAMMATIC SKETCH ILLUSTRATING THE NEW FORM OF CURRENT WEIGHER.

The electro-magnetic force between each fixed and the corresponding suspended coil is calculated from the formulæ given by Clerk Maxwell (vol. ii., p. 308), viz.:—

$$\frac{d\,\mathrm{M}}{d\,b} = -\,2\,\pi\,\cos.\,\gamma\,\left\{2\,\mathrm{F}_{\gamma} - (1 + \sec.^2\gamma)\,\mathrm{E}_{\gamma}\right\}$$

where M = the potential energy between two parallel circles, each carrying unit current,
b = distance between their planes,
a = radius of each coil,

$$\sin.\,\gamma = \frac{2\,a}{\sqrt{4\,a^2 + b^2}},$$

F_{γ} and E_{γ} = first and second complete elliptic integrals to modulus sin γ.

In one of the instruments constructed

$$a = 10{\cdot}8 \text{ inches}, \; b = {\cdot}566 \text{ inches},$$

which give

$$\gamma = 87^\circ, \text{F}_\gamma = 4{\cdot}338653976, \text{E}_\gamma = 1{\cdot}005258587;$$

from which, if G denote the constant of the instrument and $g = 981$, we have

$$\text{G} = 4 \cdot \frac{d\,\text{M}}{d\,b} \cdot \frac{1}{g} = {\cdot}4818.$$

This gives for 1 ampère a force = ·04818 gramme-weight.

Besides the one exhibited I have constructed several modifications of the instrument, only one of which, however, needs be particularly mentioned. In it both the fixed and movable coils are replaced by flat spirals of wire, each of eleven turns. Here the practical construction is more difficult, and the calculation of the constant somewhat more laborious, unless one is content with merely integrating over the area of both the fixed and suspended spirals. This is, I think, however, hardly legitimate, at least with thickish wires, as we thereby suppose that electricity is circulating in the insulating spaces between the wires as well as in the wires themselves. To avoid this I have actually calculated the force exerted by each one of the coils of the fixed spiral upon each coil of the suspended spiral. This entails great labour, as the elliptic integrals have to be calculated for values of the modulus differing very slightly from each other. The labour, however, is worth the taking, as the attractive or repulsive force between two flat spirals is so much greater than that between two simple circles.

Discussion.

LORD RAYLEIGH said the diagram and description of Prof. Blyth's instrument reminded him of the work upon which he had been engaged for the past two years. The great difference between Prof. Blyth's arrangements and those he had adopted was in the use of mercury connections instead of flexible wire. Perhaps for the scale on which Prof. Blyth was working (apparently with very large currents), the mercury connections acted very well. When he was engaged in designing his experiments it so happened that he tried something, roughly, of this kind; he tried the principle of making the connection with a mercury cup, the point where the wire dipped into the mercury being in the axis of rotation. Perhaps in consequence of imperfect arrangements, it did not result to his satisfaction, and he concluded eventually to use the flexible connection, which seemed to him really not to contain the objections which at first appeared to attach to it. Of course connection with a flexible wire could not be made without imposing a certain force upon the suspended parts. But the real question was, is that force one which can be depended upon and be eliminated from the experiments? It seemed to him it could be, because although a flexible wire undoubtedly exercised a force, still, when the suspended wires were brought into a perfectly definite position, that force must be very nearly constant, depending, of course, upon the elasticity of the material, and although it was quite true that during the passage of the electric current, and the consequent slight heating of the flexible connectors, the mechanical force exerted upon them by the suspended parts was a little different from that exerted when the apparatus was at rest, still all those observations could be taken by reversal of the current in the fixed parts of the apparatus, reversing, of course, all the forces operated. Therefore the difference of weight required to obtain equilibrium when the current was reversed in the fixed part of the apparatus gave double attraction, independently of the different force, whether mechanical or electrical, which might be exerted by the connecting wires leading the current into the suspended parts. He must say he found no reason to disapprove of results obtained in that way, but possibly with the larger currents which Prof. Blyth wished to use there might be greater difficulty in managing leading wires of that kind. The current with which he (Lord Rayleigh) had actually worked was about from one-third to one-half of an ampère, and certainly no difficulty arose with that, nor did he think any serious difficulty would have arisen if he had wished to multiply that current a few times. He would like to know whether Prof. Blyth had translated his results into terms of the silver deposited or into the E.M.F. of some standard battery. Without that his absolute results could not be compared with those obtained by previous observers. With reference to the formula quoted from Clerk Maxwell, it might perhaps be worth while to mention that he had calculated a table giving the quantity required from time to time by $\frac{d\,\text{M}}{d\,b}$ directly, therefore not requiring a reference to the original Legendre tables; and this Prof. Blyth might find useful. As to the point raised with reference to the calculation of the perfect integration of the effect of flat spirals, of course if the two flat spirals were very close to one another it might be a little precarious to assume that the mean effect was the same as if the current were continuous over the whole area. He was not sure that the calculation Prof. Blyth had mentioned met the case much better, because such a calculation seemed to assume that the current which, of course, was distributed throughout the section of each wire, was concentrated at its centre, and was that any better than the integration? He could not say at that moment how that might be, but it did not strike him that the objection to the one process was much less than to the other. He was very glad to see that Prof. Blyth had succeeded in designing so convenient an instrument for the absolute measurement of current. That was a very important matter which perhaps scarcely received the full amount of attention it deserved. A very great deal of attention had been given to the determination of electrical resistance, and many skilful workers in different parts of the world had devoted themselves to the subject. To him it seemed that the measurement of current was at least as important, even if it were not more important, but for some reason or other it attracted much less attention. He hoped Prof. Blyth would continue to work upon the subject, and that he would give his results in terms of the deposition of silver or the E.M.F. of a galvanic battery.

Prof. BLYTH said he had not tested the instrument directly with regard to the deposition of silver, but had compared it with an instrument which he believed was very accurate, one of Sir Willlam Thomson's current meters, and the result he got agreed very well with the currents as determined by that instrument. With regard to the calculation he was sorry to find on referring to Lord Rayleigh's table that it stopped at 70. If it were extended to 87 it would be a great improvement.

Mr. BOTTOMLEY said they had been working very incessantly at Glasgow on the subject of instruments of this class, and he thought they had come to a conclusion which was quite confirmed by what Lord Rayleigh had just said with regard to flexible *versus* mercury connections. They found, after a vast number of trials with all sorts of instruments, more uncertainty with the mercury connections, in consequence of the oxide which formed on the sides, than with the flexible connections, and Sir William Thomson had applied the principle of flexible connections in the form of zig-zag wire made of several, perhaps ten, small wires put together, and in these instruments they were having considerable success as against mercury cups.

Prof. ARMSTRONG said he would like to know whether any one present had made any experiments with a pretty series of flexible connections proposed by Joule. Perhaps in addition to that a series of torsional and flexible suspensions might be employed for the balance so as to avoid knife edges. But then the whole weight of the balance would have to be supported by the wires, and in that case the wires must necessarily be of great strength. These torsional and flexible connections should be so made that there should be no total torsion on the wire, the torsion on the one part compensating for the torsion on the other. He would like to extract from Lord Rayleigh, if possible, his opinion of the relative delicacy, or chances of delicacy, of this method of measuring currents and the silver voltameter method. The latter was so simple compared with Prof. Blyth's expensive apparatus, that it was of considerable importance that people interested in physical laboratories should know whether it was worth while to get standard instruments of this kind, or whether they should content themselves with merely putting up a silver voltameter.

Prof. GEORGE FORBES would be glad if Lord Rayleigh would give his opinion also as to the Clark cell. People were abolishing every sort of standard instrument except the Clark cell, and they would all like to know what Lord Rayleigh thought was the comparative accuracy attainable with instruments of the kind just described compared with that cell also. One of the chief reasons why people had not been devoting the time and attention to current measurement that they did to resistance was owing to Lord Rayleigh himself. The general opinion was that he had taken the subject so thoroughly in hand and made it so entirely his own, and that he had studied it with such very great precision in his experiments, that they might be quite contented to leave it in his hands. He specially asked the question as to the accuracy which Lord Rayleigh would expect from the system under discussion, because he could not think it was comparable in any degree in accuracy as an absolute standard with the employment of a Clark cell. He had made some experiments in the same direction himself, but he had given up altogether the idea of using the method as a standard of current, and employed such an apparatus simply as a current measurer without any magnetism in it. He was inclined to think that that was the chief use of such an apparatus. It seemed to him that there were very great difficulties in the way of making it a very exact thing. Prof. Blyth spoke of comparing his instrument with one of Sir William Thomson's accurate current meters. He did not know which instrument was spoken of, but he did not think any one of those which could have been referred to was comparable with Clark's cell for accuracy.

Lord RAYLEIGH said he did not know whether he understood clearly from Prof. Blyth whether his instrument was intended primarily for the absolute measurement of current or for continuous and daily use, for he regarded those two things as distinct. Prof. Forbes seemed to have interpreted him to mean that he used an instrument of this kind in daily use for determining currents which might occur at any moment. Clark's cell was of enormously greater value for such a purpose as that. The silver voltameter did not measure the electric current unless a certain constant were assumed. The question was whether that constant was known accurately enough. Practically, an absolute measurement of current meant the determination of the constant of the electro-chemical equivalent of silver or the E.M.F. of some galvanic cell. As regarded his own work, he endeavoured to express the results in the terms of both. If he wanted to measure a current at any moment he should use Clark's cell, and if doubtful of the result would then get it by the silver voltameter. All that came to this, that you wished to know whether what you called an ampère was an ampère. The use of the tangent galvanometer involved a knowledge of the earth's horizontal magnetic force, and that was difficult of determination. You might afterwards use your knowledge of that constant as you used your knowledge of the E.M.F. of Clark's cell. It seemed to him that the determination of the constant H was as difficult as the measurement of the current itself, if you wanted an accuracy of 1 in 1,000. If the value of H was known the comparison with the tangent galvanometer was a comparatively simple operation. If an accuracy of ½ per cent. were desired, it would be far easier to measure roughly the value of the earth's horizontal magnetism, and refer the currents to that. Even then he would prefer the silver voltameter.

Mr. R. T. **Glazebrook**, M.A., F.R.S., said that in measuring currents with the silver voltameter it was necessary to know that the current did not vary greatly during the experiment, which must last for some time, and for that reason the method with the Clark's cell was superior for most purposes.

Lord **Rayleigh** said it was a great merit of the Clark cell, that it would measure the current at any moment. The necessity of instantaneous measurement entirely precluded the use of the voltameter for the measurement of certain currents.

Mr. **Bottomley** would like to know what currents Prof. Blyth intended his instrument to measure. The currents required to be measured for electric lighting purposes were very large currents in comparison with anything he supposed his instrument was intended to measure.

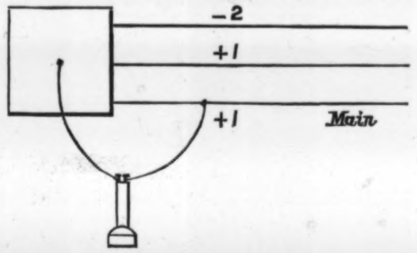
Prof. **Blyth** said the currents he had sent through the instrument varied from one ampère to ten ampères; he had used nothing higher than from ten to fifteen ampères. The real object of his design was to try by that method to find out if the calculation he had made agreed pretty well with the currents as determined by other means. No doubt the electro-chemical equivalent of silver was so perfectly determined now that perhaps determination by a battery was as accurate a method as any. But he had thought it worth while to try the experiment to see how nearly the calculation agreed with the current as got from the instrument, and what he was especially testing was not so much mercury connections as liquid connections by means either of dilute acid or any other liquid.

ON AN EXPERIMENT SHOWING THAT A DIVIDED ELECTRIC CURRENT MAY BE GREATER IN BOTH BRANCHES THAN IN THE MAIN.

By LORD RAYLEIGH.

(*Section A.—Mathematical and Physical Science.*)
Friday, September 3rd.

THIS is perhaps a somewhat paradoxical title, but I thought by so describing the experiment I might, perhaps, bring out the real point involved in it. The question is, how do conductors in multiple arc, or in parallel, behave when subjected to alternating or periodic currents? The paradox is involved in the silent introduction of the idea that the currents are steady. If they are intermittent there is no reason for supposing that the current in the main is the arithmetical sum of the currents in the branches. It must be the algebraical sum under all circumstances. The question of the behaviour of two conductors in parallel is a very easy one, if we suppose the currents to be steady. We have then the ordinary and familiar law of the division of the current between the two in proportion to their conductivities; but if the currents are alternating, and if the conductors placed in parallel have the property of self induction, which they must have in some degree, and still more if they have a sensible mutual induction one upon the other, then the case becomes very much more complicated. In a paper I published a few months ago in the *Philosophical Magazine* I gave a general calculation of what the resultant resistance of the two conductors placed in parallel to alternating currents would be, and also what the resultant self-induction of the two would be. That is to say, I gave what would be the self-induction of any single conductor. In examining that closely I saw what appeared to be very curious things involved in it, and things which would be brought out supposing the two currents placed in parallel were composed of wires led side by side so as to travel very nearly along the same course, and I think I shall perhaps best explain what I have to say by limiting myself to that. Suppose that you have three wires led side by side together and made into a coil of a considerable number of convolutions, and suppose that you take two of those wires in series and combine them in such a fashion that the current will circulate in the same way round both of those, and take that as one of the conductors in parallel, and as the other conductor in parallel take the third wire, and then submit the system composed of those three wires forming two conductors in parallel to alternating currents, what will be the condition of the currents between the two conductors there, and how will they be related to the current in the main? Well, the theory shows that when the rapidity of alternation is sufficiently great that the endeavour, as it were, is to cause the magnetic effect of the combined currents to be as small as possible at points which they influence, in fact, to neutralise as far as possible the magnetic effects, and that tendency more and more asserts itself as the rate of alternations increases, as the inductive coefficients increase, so that ultimately the distribution of currents comes to be independent almost completely of resistance, and to depend only upon the induction coefficients. And in this peculiar case, as you may see at once, the energy of the field of magnetisation at various points not quite in the immediate neighbourhood of the three wires, may be, in the distribution of the current, neutralised, because we have only to suppose that the current of the two wires joined in series is just half that, and in the opposite direction to that in the single wire in order to have at all points complete neutralisation of effect; so that under the influence of rapid periodic currents this is the state of things. But as you see, what is involved in that is this: The current in the one conductor, in the two wires placed in series, should be represented by + 1, the current in the single wire by − 2, and the current in the main by + 1, numerically less than one of the currents in the branches. This is perhaps the easiest form in which to make the experiment. It so happened that I had a large coil triply wound, and I tried the experiment in the form in which I have related it. In order to estimate the currents in the three conductors I adopted the plan of having a piece of copper sheeting fastened to a board and three German silver wires fastened to it. The current was tested by a process in which the telephone was used. Another wire was soldered to the copper sheeting and went to one pole of the telephone, and the German silver wires were connected by touching at various points, so that if the currents had been equal in those three wires, the sounds produced by touching at the second telephone terminal would have appeared equal. It was found at once that the current in one of the branches was very much stronger than the current in the other branch, and more than equal to that in the main. Knowing what one wants, it would perhaps not do to trust to one's self, still by putting an assistant at the telephone, and by trying various places, it is possible to feel out the quality of the current so as to get something like a numerical estimate of it in this way. But I was not quite satisfied with that. I have said in my title, greater in both branches than in the main. I have arranged something else, but the principle is just the same. It involved iron, and it is most easily understood by having five wires instead of three. I combine them so that three are in series and two are in series; but the three in series are to be combined in parallel with the other two in series, so that in that way, in order to get neutralisation of magnetic effect at a distance, it is necessary that the currents in the two branches in parallel must be in the opposite proportion taken negatively. The currents must be in the proportion of + 3 and − 2. That is the state of things; consequently both are numerically greater than the current in the main, which is + 1. I have verified it sufficiently to show that there is no difficulty whatever in so arranging the thing that the currents in both branches are decidedly greater than that in the main. Perhaps I might just say for the information of anybody who may wish to repeat the experiment, that it is a very easy one indeed, if you have a suitable coil to work upon. I used a scraping contact only, a battery and scraping contact to give the sound of the induction of the telephone. There was just a slightly perceptible difference in quality and degree when the sounds were caused to be as nearly equal as possible by varying the lengths of the wires, but not enough to interfere in any way with the experiment.



ON A NEW SCALE FOR TANGENT GALVANOMETERS.*

By W. H. PREECE, F.R.S., and H. R. KEMPE.

(*Section A.—Mathematical and Physical Science.*)
Wednesday, September 8th.

TANGENT galvanometers are much used for the exact quantitative measurement of currents of considerable strength, such as are measured in ampères, but they are not so generally used for the measurement of smaller currents in milliampères. This arises from a notion that they are not sensitive enough, although the most sensitive instrument in practice—Sir William Thomson's mirror galvanometer—is really a tangent instrument. The ordinary forms, Joule's, Gaugain's, or Helmholtz's, are not very sensitive. Their constant is about 3; that is, 3 ampères are required to produce the unit deflection of 45°. The Post Office has for many years used a more sensitive and portable form having a constant of ·00214 for testing wires, batteries, and apparatus.

Fig. 1 shows in elevation the general form of the instrument.

Fig. 2 is a general plan of the arrangement of the coils, &c.

The ring, which is 8 inches in external diameter, has three coils of wire wound on it. The one nearest the needle is of No. 35 wire, and is wound to a resistance of 320 ohms approximately. The other two coils are of No. 18 gauge; the one between C and D making three turns, and the one between D and E making 12 turns in the opposite direction. The latter coils are for testing batteries; by using terminals C D, D E, or C E, respectively, relative degrees of sensitiveness of approximately 1, 3 and 4 can be obtained. An adjusting magnet, similar to that used on the ordinary Thomson mirror galvanometer, is set on the upper part of the ring as shown. In testing the strength of a current in milliampères by means of the instrument a standard Daniell cell is connected between terminals A and B; both plugs being removed from the plug holes, *a*, *b*, there is in circuit a total resistance of 1,070 ohms, viz., 750 + 320. As the electromotive force of the standard cell is 1·07 volts, the resulting deflection (30°) of the galvanometer needle will be due to a current of 1 milliampère. By means of the adjusting magnet this deflection can be increased or diminished as required. In practice, the adjustment is such that 1 milliampère of current gives a deflection of 80 divisions on the ordinary tangent scale. When the measurement of a current is to be made a plug is usually inserted so as to cut out the 750 ohms resistance. Another plug inserts a $\frac{1}{10}$th shunt.

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* In presenting the description of this instrument Mr. Preece said he would not read the full paper as Sir William had just informed him that he invented and patented a precisely similar instrument three years ago.

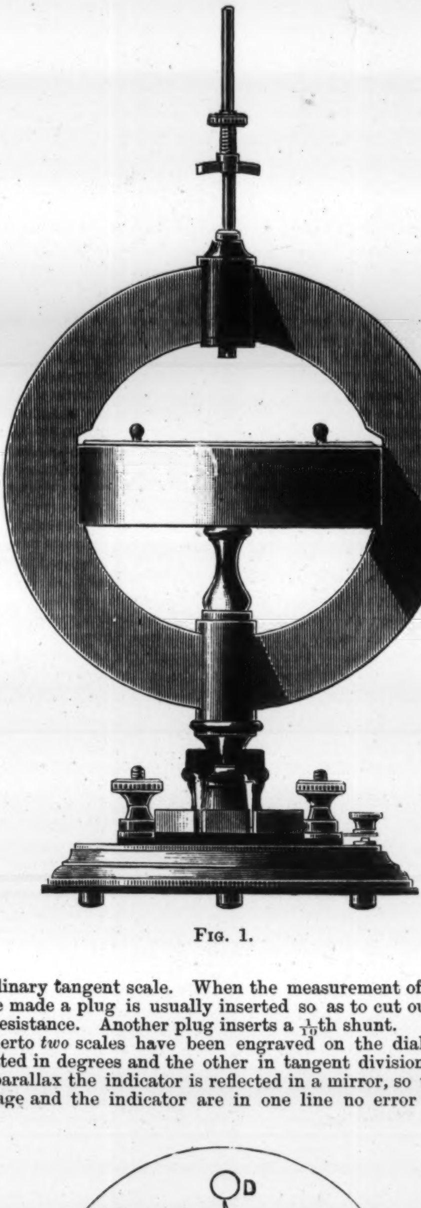


FIG. 1.

Hitherto *two* scales have been engraved on the dial, the one graduated in degrees and the other in tangent divisions; and to avoid parallax the indicator is reflected in a mirror, so that when the image and the indicator are in one line no error from this cause occurs. Where observations are made by reading deflections serious errors arise from parallax, especially where the law of tangents is followed.

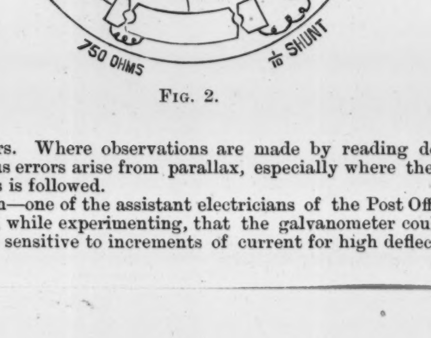


FIG. 2.

Mr. Eden—one of the assistant electricians of the Post Office—discovered, while experimenting, that the galvanometer could be made more sensitive to increments of current for high deflections if it were given a false zero. In fact, if the instrument be "slewed" round so that the plane of the coil makes an angle of 60° with the meridian, then the instrument becomes twice as sensitive as it was before, and he suggested a double scale such as is shown in the following figure to utilise this fact. This plan has been adopted, and all tangent galvanometers in the Post Office service will be gradually altered to the new scale (fig. 3).

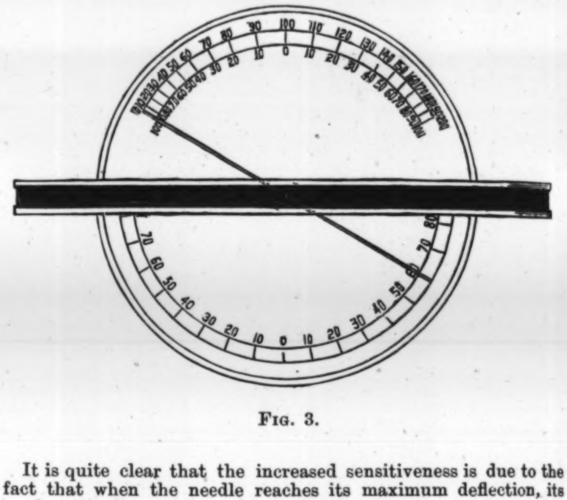


FIG. 3.

It is quite clear that the increased sensitiveness is due to the fact that when the needle reaches its maximum deflection, its angle to the lines of force of the field is the one most favourable for the deflective action of the current. In fact, the plane of the coil becomes parallel to the plane of the needle, which is then in the most *uniform* portion of the field.

It becomes most desirable to know if the divisions under these conditions are still proportional to the current strengths.

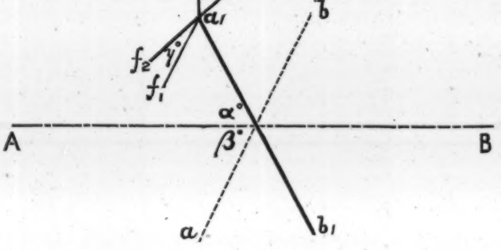


FIG. 4.

Let the dotted line, A, B, represent the plane of the coil ring, and let a_1, b_1, be the needle which has been deflected from the normal position, a, b, the angle which the needle normally makes with the coil being $\beta°$. Let $a°$ be the angle to which the needle has been deflected to the other side of the coil, then deflective force, f, of the coil resolved at right angles to the needle is

$$f_2 = f \cos. a° \, k$$

where k is a constant.

Also force f_1 of earth's magnetism, which acts parallel to a, b, resolved at right angles to the needle is

$$f_2 = f_1 \cos. \gamma° \, k$$

therefore

$$f \cos. a° = f_1 \cos. \gamma°$$

or

$$f = f_1 \frac{\cos. \gamma°}{\cos. a°}$$

but

$$\gamma° + 90° + a° + \beta° = 180° \quad \therefore \quad \gamma° = 90 - (a° + \beta°)$$

from which

$$\sin. \gamma° = \sin. (a° + \beta°)$$

therefore

$$f = f_1 \frac{\sin. (a° + \beta°)}{\cos. a°} = f_1 \frac{\sin. a° \cos. \beta° + \sin. \beta° \cos. a°}{\cos. a°} \text{(A)}$$

$$= f (\tan. a° \cos. \beta° + \sin. \beta°) = f \cos. \beta° \left\{ \tan. a° + \frac{\sin. \beta°}{\cos. \beta°} \right\}$$

$$= f \cos. \beta° (\tan. a° + \tan. \beta°)$$

so that $\cos. \beta$ being a constant quantity the strength of a current is directly proportional to ($\tan. a° + \tan. \beta°$), which is the reading on the tangent scale if the figures on the latter are rearranged so that the zero is at the division at which the needle points in its normal position.

By thus changing the zero of the instrument the range of movement can be considerably increased; thus if β° be the angle which the needle normally makes with the coil, and if α° be the angle to which the needle has been deflected on the other side of the coil, then f being the deflective force, we have

$$f = f_1 \frac{\sin.\,(\alpha^\circ + \beta^\circ)}{\cos.\,\alpha^\circ}$$

when f_1 is a constant, but if the needle were parallel to the coils, then

$$f = f_1 \tan.\,\alpha_1$$

therefore

$$f_1 \frac{\sin.\,(\alpha^\circ + \beta^\circ)}{\cos.\,\alpha^\circ} = f_1 \tan.\,\alpha^\circ_1$$

Now if we have $\beta^\circ = 60^\circ$, and if the current be sufficient to turn the needle through $2\,\beta^\circ$ or 120°; that is, if we have $\alpha^\circ = 60^\circ$, then

$$\frac{\sin.\,120^\circ}{\cos.\,60^\circ} = \tan.\,\alpha^\circ_1$$

but $\sin.\,120^\circ = \sin.\,(180^\circ - 60^\circ) = \sin.\,60^\circ$ therefore

$$\frac{\sin.\,60^\circ}{\cos.\,60^\circ} = \tan.\,\alpha^\circ_1 = \frac{\sin.\,\alpha^\circ_1}{\cos.\,\alpha^\circ_1}$$

or

$$\alpha_1 = 60^\circ$$

that is to say, the angle through which the needle would have been turned when the zero was 60° to one side of zero would be twice what it would be if it had been deflected from the ordinary zero. The ratio of these angles, however, decreases in value, and at a certain point becomes equal to 1; that is to say, the angular deflection from the new zero is the same as it is from the old zero.

Let

$$\frac{\sin.\,(\alpha^\circ + \beta^\circ)}{\cos.\,\alpha^\circ} = \tan.\,\alpha^\circ$$

therefore

$$\frac{\sin.\,(\alpha^\circ + \beta^\circ)}{\cos.\,\alpha^\circ} = \frac{\sin.\,\alpha^\circ}{\cos.\,\alpha^\circ},$$

or

$$\sin.\,(\alpha^\circ + \beta^\circ) = \sin.\,\alpha^\circ.$$

If the angle, α°, is negative, that is to say, if the angular deflection from the new zero is less than the angle, β°, then we have

$$\sin.\,(\beta^\circ - \alpha^\circ) = \sin.\,\alpha^\circ,$$

or

$$\beta^\circ - \alpha^\circ = \alpha^\circ;$$

that is

$$\beta^\circ = 2\,\alpha^\circ,$$

or

$$\alpha^\circ = \frac{\beta^\circ}{2};$$

that is to say, whatever be the angle, β° (the angular distance of the new from the old zero), then a current sufficient to move the needle a distance of $\frac{\beta^\circ}{2}$ from the old zero would move the needle the same distance from the new zero. *If the deflection from the old zero be less than* $\frac{\beta^\circ}{2}$*, then the deflection from the new zero will be less still,* so that there is no advantage in the use of the new zero unless the deflections exceed $\frac{\beta^\circ}{2}$.

If the angle, β°, be made greater than 60° than the possible angular movement of the needle becomes still further increased; but inasmuch as any increase in the length of the tangent scale brings the divisions at the ends of the scale proportionally closer together and more difficult to read from, there would be no practical advantage in making the angle larger. A marked advantage, under certain conditions, is found when the new zero has such a value that the deflection from a given current causes the needle to turn up to the ordinary zero, that is to say to the position where the needle becomes parallel to the coil; in this case the instrument becomes highly sensitive, and any increase in the strength of the current produces a very considerable change in the deflection.

Thus, supposing the new zero to be, as before, 60°, then if after the needle had been deflected to the old zero the current which had caused this deflection had increased 10 per cent., then the deflection, α°, beyond the ordinary zero would be such that

$$\tan.\,\alpha^\circ + \tan.\,60^\circ = \tan.\,60^\circ \times \frac{110}{100},$$

or

$$\tan.\,\alpha^\circ = \tan.\,60^\circ \left(\frac{110}{100} - 1\right) = 1{\cdot}7320508 \times \frac{10}{100}$$

$$= {\cdot}17320508 = \tan.\,9^\circ\,50'.$$

If, however, the deflection had been from the old zero in the first instance, then this deflection, γ°, would have been such that

$$\frac{\sin.\,(0^\circ + 60^\circ)}{\cos.\,0^\circ} = \tan.\,\gamma^\circ,$$

or

$$\sin.\,60^\circ = \tan.\,\gamma^\circ;$$

therefore

$${\cdot}8660254 = \tan.\,\gamma^\circ_1$$

or

$$\gamma^\circ = 40^\circ\,54'.$$

If the current under these conditions were increased 10 per cent., then the increased deflection, γ°_1, would be such that

$$\tan.\,\gamma^\circ_1 = {\cdot}8660254 \times \frac{110}{100} = {\cdot}95262794 = \tan.\,43^\circ\,37',$$

which is an increase of

$$43^\circ\,37' - 40^\circ\,54' = 2^\circ\,33'$$

as against 9° 50′ when the deflection was taken from the new zero, an increased sensitiveness of over 4 : 1 in favour of the new zero.

If the angle, β°, had been 85°, then an increase of 10 per cent. would move the needle as much as 48° 45′ beyond the ordinary zero. It might then seem that the greater β° is made the better; but there is a practical limit to this increase, for the larger we make β the more does the deflective action of the coil tend to act in a direction parallel but opposite to the earth's magnetism, the consequence being that the resultant of the two forces is a comparatively small quantity, and the friction of the pivot, &c., prevents the needle from settling down to the true angle representing the force of the current. Under such conditions very large errors in the readings may result. Were it not for this fact the instrument would increase in actual sensitiveness up to that point at which $\beta^\circ = 90^\circ$, at which point the needle would not move unless acted upon by a current exceeding in deflective force the intensity of the earth's magnetism; when the current exceeded this value the needle would swing completely round through an angle of 180°.

ON AN ELECTRIC MOTOR PHENOMENON.

By W. M. MORDEY.

(Section A.—Mathematical and Physical Science.)

Tuesday, September 7th.

ON the occasion of running and testing a Victoria Electric Motor in the works of the Anglo-American Brush Electric Light Corporation an unexpected phenomenon presented itself to the writer and his assistant, Mr. Watson. The motor was a 30 H.P. series-wound high-tension machine, constructed to work with a current of 20 ampéres. When the driving generator (a large Brush machine wound for 20 ampéres) was started, the motor, being connected in the circuit, also started, but ran slowly and developed but little power. As there was apparently some fault in the connections, or elsewhere, it was necessary to examine the machine and circuit. In order to stop the motor the circuit was broken by taking one of the leads out of the terminal to which it was connected. On doing this, the motor, which at the time was running slowly in the usual direction, stopped suddenly, and instantly ran backwards, *i.e.*, in a direction reverse to that which was usual, at a rate of speed rather greater than its former forward rotation, slowly decreasing in speed until it stopped. It appeared at the first glance as if some connection still existed with the generator, but this was not the case, and it became evident that the machine contained within itself the cause of this behaviour. An examination of the circuit revealed the fact that the fields of the motor, instead of being joined in series with the armature, had by mistake been placed as a shunt across it. Otherwise everything was in proper order. When the connections were put right the motor ran without any unusual feature. An examination and some experiments with this and other machines were made to ascertain the cause of this unexpected reversal of the direction of rotation.

In considering the action it will be seen in the first place that the slow speed at which the motor ran when connected with the generator was the result of the smallness of the current in the armature. The winding being intended for a series connection, the resistance of the fields was comparatively low, and when the armature and fields were connected in parallel, almost a normal field was produced, the armature receiving only a small portion of the current. To understand what took place when the circuit of the generator was opened it is only necessary to consider the case of any shunt motor. We know that when a motor is running its E.M.F. is, as it were, always trying to send a current in an opposite direction to that which is being forced through its armature. On cutting off the supply of current, this opposing E.M.F. is able to assert itself, and the motor becomes converted into a generator. The momentum of the armature and of any machinery that is being driven, keeping up the motion for a short time, and causing the armature to generate a current, which circulates through the armature and field. In fact, the shunt motor under such conditions acts like a series generator with its terminals short circuited, the momentum of the armature and of any connected machinery being quickly exhausted, and the armature coming to rest. The intensity of this braking action depends to some extent upon the form of the "characteristic" of the machine when working as a generator. Properly constructed shunt motors, having fields wound to a comparatively high resistance, do not show this action to any marked degree, unless a suitable external circuit is provided, because the high resistance of the field circuit prevents the generation of more than a small current; and shunt motors which are incapable of acting as shunt generators do not exhibit it at all; but most machines which are provided with shunt fields, the resistance of which is low, show it very clearly, and in a series machine on short circuit, that is to say, working merely through its own low resistance fields, as in this case, the action may be very strong, especially if the generating "characteristic" is not readily made to drop. Thus the armature is quickly brought to rest. But this does not explain why when it had actually stopped the armature started again in the opposite direction with a considerable velocity. This will be understood by referring to the figures. Fig. 1 shows the connections and the course of the current when the motor is supplied with the current, and when it may be supposed to be running forward in obedience to the action of the current. Fig. 2 shows the direction of the current under the two conditions which successively occur when the external circuit is broken. In the first place, as already explained, on opening the external circuit, the momentum of the armature causes a current to be generated, which it will be seen flows through the armature in a direction opposite to that in Fig. 1, but in the same direction in the fields as before. This at once stops the armature unless the momentum is very great. Secondly, the momentary induced (extra) current follows in the same direction, at the moment when motion has ceased, and causes the armature to start again in the reverse direction.

This extra current is produced in both the armature and field-magnet coils, but mainly in the latter, as the self-induction in them is comparatively great. It may be of interest to add that the motor in question has for several months been working very successfully in New Zealand, where it is used to supply power to the machinery at the Phœnix Gold Mines. The current is generated by Brush dynamos, driven by water power at a considerable distance from the mine, and is conducted to the motor by means of a copper wire the size of an ordinary telegraph wire (·165 inches in diameter) supported on poles. The total length of the conductor is six miles.

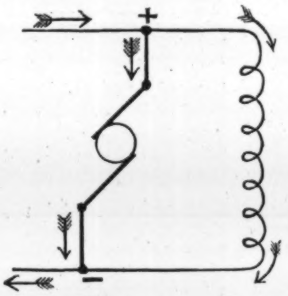


FIG. 1.

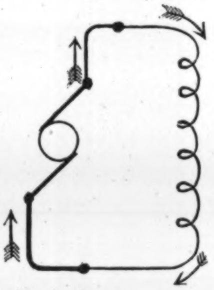


FIG. 2.

This is a case of the installation, amongst the mountains of a remote colony, of apparatus by which 30 H.P. is being transmitted by a wire, of which five miles weigh less than a ton, with an effective useful return of over 65 per cent., no skilled labour being supplied or required. There is nothing in this instance of transmission which scientific men can regard as novel, but it is an eminently practical one, and I may perhaps, therefore, be permitted to draw attention to it in this place, because although a great deal has been written as to the possibilities of the electrical transmission of power, there is a scarcely-concealed scepticism on the subject amongst practical men.

It had been proposed to utilise the braking power of motors by turning this momentum to account for the purpose of stopping them. I do not think this should be done. If power is to be wasted, by all means waste it in the brake block, or somewhere where it can do no harm, and not in a dynamo, where excessive and sudden loads are very objectionable. Only in two cases would I recommend the use of motors as generator brakes. First, where admission or accident of some kind could thereby be prevented; and, second, where the power generated could be utilised and not simply wasted in heating the machine.

While speaking of electric motors, another point may be mentioned, which is of some interest.

M. Marcel Deprez's experiments in France failure seems to have been caused by the extra currents induced on opening the circuit of the motor, breaking through the insulator, and special precautions have been taken to reduce the current very considerably before the circuit is opened. In motors this is less necessary than in generators. It is well known that if the armature circuit of the shunt generator is opened, a very considerable arc may be formed by the combined generator of the current at the moment of breaking the circuit and by the extra current. In series generators a similar, but perhaps more severe effect is produced, although if suitable care in construction is taken no breach of insulators need occur. Brush generators give from 2,000 to 3,000 volts and 10 ampères, and I may mention that I have frequently opened the circuit by withdrawing one of the wires from its terminal, and I have never broken down a machine by doing so, although the arc which has followed the wire has been fully 12 inches in length. But what I wish to point out is the difference between the behaviour of a shunt generator and a shunt motor if the armature circuit is opened. In the case of the former a very severe arc may be formed, as everybody knows who has lifted one of the brushes when such a machine was running. But in the latter case—that of a shunt motor—one of the brushes may be removed from the commutator with the formation of only a very small arc. It will readily be seen why this is so. In the motor armature there is an opposing E.M.F. very nearly equal to the supplying E.M.F., and consequently the extra current effect is greatly subdued, any extra current from the line passing through the field magnet coils. The problem of how to stop a motor without first stopping the generator seems to me, therefore, to be a very simple one, and undeserving of the very elaborate and ingenious devices which have been combined necessary in connection with the very interesting experiments already alluded to, which have been going on for some years in France.

To stop the current at the generator possibly requires more care, and when the machine cannot be readily stopped the excitation of the fields should be perhaps reduced before opening the armature circuit.

The case of a series motor is rather different, but is not the same as a series generator, as it is practically only the extra current from the field magnets which has to be considered.

ON THE ELECTROLYSIS OF SILVER AND COPPER AND ITS APPLICATION TO THE STANDARDISING OF ELECTRIC MEASURING INSTRUMENTS.

By THOMAS GRAY, B.Sc., F.R.S.E.

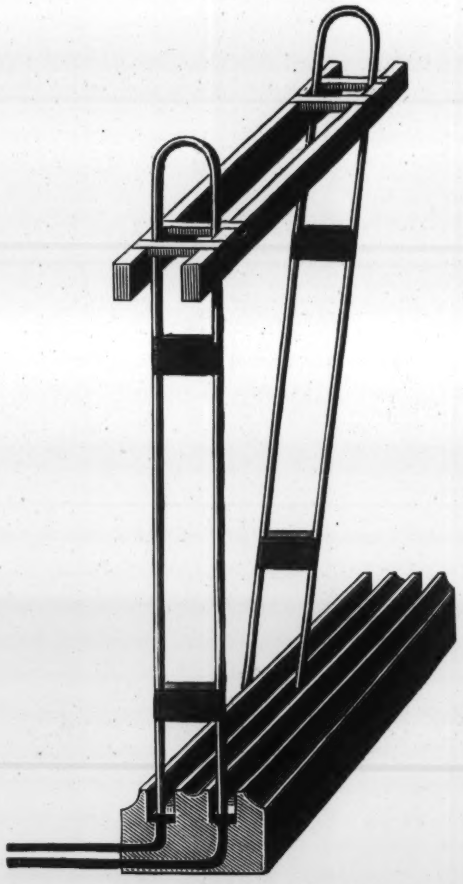
(*Read by* MR. J. T. BOTTOMLEY.)

(*Section A.—Mathematical and Physical Science.*)

Thursday, September 2nd.

[ABSTRACT.]

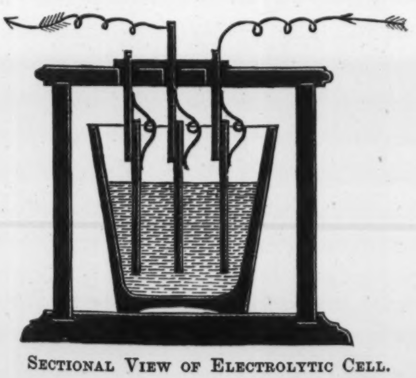
THIS paper contains an account of a large number of experiments on the electrolysis of silver and copper and its application to the standardising of electrical current and voltmeters which have been made during the past year in the Physical Laboratory of Glasgow University, it forms a summary of the reports made from time to time to Sir William Thomson on this subject.



VIEW OF CONNECTING BRIDGE.

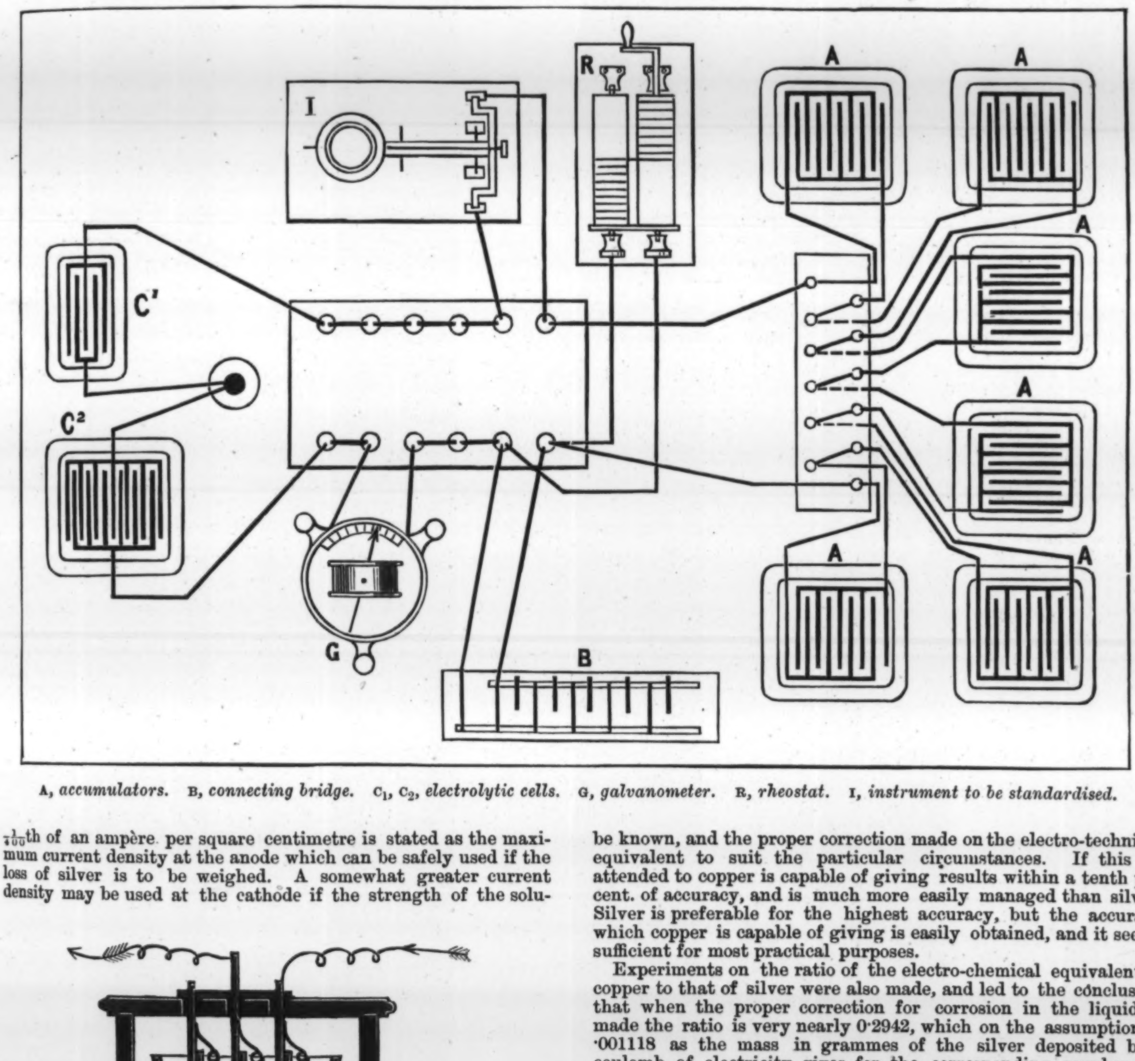
In the earlier experiments pure silver sheet and solutions of pure silver nitrate were used for the electrolytic cells. The results obtained with these cells confirmed those obtained by Kohlrausch, Lord Rayleigh, and other observers as to the great accuracy obtainable with silver, and also as to the nature of the deposit and the care required in the manipulation of the experiment.

The cathode plate consisted in almost all cases of a sheet of pure silver placed with its plane vertical between two parallel sheets of the same metal. In a few experiments a platinum bowl was used very much in the same manner as that described by Lord Rayleigh in his paper to the Royal Society, but generally the plates of sheet silver were preferred. The mode of treating the plates both before and after the deposit was upon them is fully described, and it is pointed out that when the plate is made thoroughly clean and its size properly proportioned to the strength of the current to be measured, the deposit is finely crystalline and adheres very firmly to the plate. The best results were obtained when the current density at the cathode is between the $\frac{1}{200}$th and the $\frac{1}{600}$th of an ampère per square centimetre of the surface on which the deposit is taking place, the solution being supposed to contain 5 per cent. of silver nitrate. It is also pointed out that the loss of silver from the anode can be used satisfactorily as a check on the amount of silver deposited on the cathode, but that the current density at the anode must be considerably smaller than that which will give good deposits on the cathode. About $\frac{1}{400}$th of an ampère per square centimetre is stated as the maximum current density at the anode which can be safely used if the loss of silver is to be weighed. A somewhat greater current density may be used at the cathode if the strength of the solution be increased, but the deposit is more roughly crystalline and less adherent. The current density cannot be increased in nearly the same proportion as the increase in the amount of silver nitrate in the solution, and hence when sheet silver cathodes are used the most economical and most satisfactory method is to use weak solutions and large plates. Rolled silver gives unsatisfactory results until the outside skin has been removed by use, polishing, or scraping. The latter experiments described in the paper refer, for the most part, to copper and include experiments on the uncertainty likely to arise from the oxidation of the plate in drying and while in the solution; the effect of the loss of weight due to direct chemical corrosion of the plates; the effect of density of solution of size of plate or current density; and of the addition of acid to the solution. It was found that there is no difficulty in washing and drying a plate without oxidising it sensibly, and methods are described for doing this. The loss of weight by corrosion in the liquid introduces an error which is nearly proportional to the surface of the plate exposed, and judging from Dr. Gore's experiments it is also no doubt influenced by the temperature, if that be not constant; but the effect of temperature was not investigated. The amount of corrosion is also influenced to some extent by the density of the solution, and it appears to be least when the density is between 1·15 and 1·10.



SECTIONAL VIEW OF ELECTROLYTIC CELL.

It is concluded that in the use of copper for standardising purposes, the current density and the density of the solution must be known, and the proper correction made on the electro-technical equivalent to suit the particular circumstances. If this be attended to copper is capable of giving results within a tenth per cent. of accuracy, and is much more easily managed than silver. Silver is preferable for the highest accuracy, but the accuracy which copper is capable of giving is easily obtained, and it seems sufficient for most practical purposes.



A, *accumulators.* B, *connecting bridge.* C_1, C_2, *electrolytic cells.* G, *galvanometer.* R, *rheostat.* I, *instrument to be standardised.*

Experiments on the ratio of the electro-chemical equivalent of copper to that of silver were also made, and led to the conclusion that when the proper correction for corrosion in the liquid is made the ratio is very nearly 0·2942, which on the assumption of ·001118 as the mass in grammes of the silver deposited by 1 coulomb of electricity gives for the corresponding number for copper ·0003290 When a nearly saturated solution of copper sulphate is used and a current density of $\frac{1}{50}$th of an ampère per square centimetre of the cathode, the amount of copper deposited by a coulomb of electricity is ·0003287 gramme.

It is pointed out that if the solution does not contain free acid there is a danger of obtaining too great an increase of weight, due apparently to the oxidation of the copper as it is being deposited. The same remark as that made above with regard to the silver anodes applies to the copper anodes if they are to be weighed. If the copper anodes are so small as to give a current density exceeding about the fortieth of an ampère per square centimetre the current is liable to stop almost completely, even when an electromotive force of as much as 25 volts are used to produce it; this is apparently due to excessive resistance at the surface of the anode. After a few minutes the current will again resume nearly its old strength and gases will be given off freely at the anodes.

These gases are readily dissolved by the liquid, and generally as the final result the gain and loss of copper do not differ very greatly, although they always do differ from those obtained when no gases are given off.

Lastly, the arrangements of one of the standardising tables in Sir William Thomson's laboratory are illustrated, and the different pieces of apparatus and the mode of using them described.

DISCUSSION.

Prof. SILVANUS THOMPSON desired to know what galvanometer was employed for keeping the current constant.

Mr. BOTTOMLEY replied that any instrument that was sufficiently sensitive might be used.

Prof. THOMPSON said he supposed all the measurements assumed H constant.

Mr. BOTTOMLEY said H remains constant during the hour. He did not know whether he had been misunderstood. The object of the whole thing was to standardise a current measuring instrument by electrolysis.

Prof. THOMPSON was afraid H would not remain constant for an hour in his laboratory among dynamos, &c.

LORD RAYLEIGH said he supposed the constancy of the galvanometer was not an essential part of the apparatus. In point of fact when he wanted to obtain the highest accuracy he found it was best to leave the current alone, and take the mean of the current readings at the beginning and end of the time. Of course it was far more convenient for calculation to control it in the way Mr. Bottomley had described by means of the galvanometer and rheostat.

Mr. BOTTOMLEY: That is quite so; it is simply for convenience.

LORD RAYLEIGH said he would like to know whether Mr. Bottomley did not find, in using a vertical arrangement of plates, whether of silver or copper, that he was troubled with the necessary tendency of the liquid to assume unequal density. It might be that with large masses of liquid the effect was not important; but in his experiments with silver he had found it decidedly an advantage to keep the plates horizontal, having the anode horizontal near the surface so that the liquid which collected there might circulate itself by gravitation about the plate. He questioned whether it was really the best plan to pass such very heavy currents as Mr. Bottomley spoke of—from 50 to 100 ampères—through voltameters at all. It would not be very difficult to contrive apparatus, a sort of shunted galvanometer, which should show with precision when one current was exactly twenty or thirty times another. In that case the heavy current to be dealt with would be passed through the instrument to be standardised at the same time that the current twenty or thirty times smaller passed through the voltameter. That occurred to him as the best way of measuring very great currents with great accuracy rather than to pass the great current itself through the voltameter.

Mr. BOTTOMLEY said, with regard to the density question, they had not been troubled with the change in density. They had a large number of plates; there were in all nineteen in their instruments, nine cathodes and ten anodes, and an electrolytic vessel containing perhaps 30 or 40 lbs. of solution. They were brought close to each other, and no doubt current must be circulating in them. He thought large currents, 200 ampères or more, a method of graduating somewhat similar to that Lord Rayleigh had referred to, would be useful. Sir W. Thomson has occasionally graduated two or three instruments with smaller currents, then putting these in multiple arc, taking the whole current from them through an instrument to be graduated with a strong current, and has had very good results.

Prof. BLYTH wished to know something more respecting the rheostatic interference with the current strength during the period of measurement. Was it exactly the same thing in measuring the quantity of electricity going through the electrolytic apparatus if it were applied for ten alternate periods of one minute and then for ten consecutive minutes? He could not quite see why it should not be, but it was quite possible that it might not be exactly the same thing. If it were, the rheostatic interference with the current strength during the time of measurement would require to be seriously looked into.

Mr. SHAW said he had seen a number of experiments on the comparison of silver and copper electrolytic cells, and he would like to remark upon one point introduced by Mr. Bottomley, who had spoken of the determination of the quantity by the loss of weight of the anode as well as by the gain of weight of the cathode, and mentioned a difficulty which those who worked with copper voltameters were perfectly familiar with, that was to say, that after a current had passed for some time it very rapidly fell. It might recover again two or three minutes afterwards, but there was that sudden drop in the current which sometimes seriously interfered in experiments with standardising instruments. That seemed to him to be due to the oxide in the copper, or whatever the anode might be; but, as a matter of fact, it wiped the layer off, and a rehabilitation of the current was at once obtained. Even in the case of silver, although the oxide did not occur there, the current in its action upon the anode seemed to be selective; it did not take a uniform layer, but disintegrated the metal as it took off the silver, and that, although it might be reduced to a minimum in certain particular experiments, could never by any arrangement of the apparatus, so far as he could make out, be actually avoided. A particular experiment might succeed in consequence of the peculiar molecular construction of the silver, but generally the result was greatly interfered with by reason of this disintegration and consequent falling away of the metal. The hard or oily layer on the surface of the silver was very apparent, but even when they got below that and used surfaces originally left by electrolytic action—even there, there was a selective action of the current upon the anode, and it was only when the anode was of considerable size that any satisfactory weighing of the anode could be obtained. The current he had worked with was very much smaller than the currents Mr. Bottomley had mentioned, being about half an ampère or less. This difficulty must be very considerably increased in this case owing to the proximity of the plates.

Prof. ARMSTRONG asked Mr. Bottomley what method of drying he had employed. Of course, chemists now obviated the difficulty in this respect by drying very rapidly, usually by washing first of all with distilled water and then with ether possibly to dry the plates after the washing. He spoke of this because chemists were in the habit of using electro-deposition for a very large number of determinations.

Lord RAYLEIGH supposed Mr. Shaw's remarks related rather to the anode than to the cathode.

Mr. SHAW: Yes.

Mr. BOTTOMLEY did not know if anybody had made any experiments on a subject mentioned by Professor Blyth, that of starting and stopping the current. He did not see why stopping and starting should make any difference, though it would make instruments difficult to read. With regard to weighing the anode plates, it was only used as a check upon the other method; they really went by the cathode. If the anode were to give a bad result it would be put aside. It was mentioned only as a matter of interest, and as showing that the anode could be used if the dimensions were properly arranged. With regard to drying the plates, they simply put them between two folds of blotting paper, squeezed the water out, and then exposed them to fire or to the hot current of air over a spirit flame.

Professor OLIVER LODGE said he had always found the copper come out 1 per cent. higher than the silver result. He supposed, however, the method was sufficient for rough graduation. The difficulty in drying copper and weighing it before oxidation occurred was very much too considerable for accurate working; silver was very much easier to deal with.

Professor SILVANUS THOMPSON said that checking the current after first turning it on could to some extent be avoided by using small current density. An experiment given in the first chapter of "Planté's Researches on Secondary Batteries" was admirably calculated to show the three stages of the process occurring at the first turning on. The phenomenon was most marked when two copper wires were used as electrodes with a very considerable current density.

Mr. BOTTOMLEY said he should be very sorry if it was supposed that the experiments described in the paper were merely for the purpose of rough graduation. They considered that the experiments were good to $\frac{1}{10}$th per cent., and it was not a matter of being sure to 1 per cent. or anything like it. He thought if the precautions which they had discovered to be necessary in the course of these experiments were adopted, no very serious difficulty would be found in the way of washing or drying the plates. The plates obtained and treated in the way described were obviously not oxidised; after drying them they could leave them for hours, and the weight was not perceptibly different. The great thing was, perhaps, with regard to avoiding the oxidation during the time when the current was flowing, and that was accomplished by making the solution of the proper density, and keeping it slightly acid. In neutral solutions they always found oxidation, and to a very serious extent.

Mr. SHAW said he could corroborate Mr. Bottomley's statement with regard to the oxidation of the anode when the current density was adjusted with sufficient carefulness. For other current densities the oxidation was equally marked as soon as the plate began to dry. This was a point upon which he was having some communication with Prof. Lodge for the purposes of the Electrolytic Committee, and therefore he would say no more about it at present.

ON THE TREATMENT OF SECONDARY BATTERIES.

By BERNARD DRAKE and J. MARSHALL GORHAM,

(Section G.—Mechanical Science.)

Monday, September 6th.

THE possession of a reliable means of storing electrical power is now universally recognised. For electric lighting, whether temporary or permanent, whether domestic or public, it is almost an essential—for the commercial application of electricity to motive power it is a necessity.

The theory of secondary batteries or accumulators, by means of which this storage is attained has already been so ably dealt with, and is, probably, so well known to all present, that it is unnecessary to enter into it in this short paper, the object of which is to bring to your notice some practical points of treatment which are essential, in order to render secondary batteries commercially reliable.

These points have been arrived at by experiments carried on by Mr. Gorham and myself, in the course of the manufacture of the batteries of the Electrical Power Storage Company.

The three main difficulties which we had to encounter were:—1. The destruction of the lead grid or conductor. 2. The buckling or warping of the plates. 3. The falling out of the active material.

These three failings, principally affecting the peroxide plates, militated seriously against the commercial success of accumulators, of which durability forms so important a factor.

We, therefore, carried out a large number of experiments, with a view to ascertain their various causes, and, by removing them, to render the secondary battery with which we had to do, as reliable for durability as it already was in other respects.

Here I may mention that these failings, although common, were by no means universal. For instance, the E.P.S. accumulators in the Bank of England have been in use more than 2½ years, and continue to give excellent results. That they do so confirms the conclusions to which experiment has led us.

We will take first:—1. The destruction of the lead grid or conductor. This was the most serious difficulty to face, as on it depended the life of the battery.

The prevalent idea was that it was due to overcharging; that after the peroxide plate was fully charged any further charge caused an evolution of oxygen which rapidly destroyed the grid. We therefore proceeded to charge some cells without cessation in order to ascertain the exact amount of current which would entirely destroy the lead conductor, or grid. It was soon evident that the process was, at any rate, a slow one; but the experiment was continued, until the full prescribed current had been passed through, for more than two months. At the end of that time it was found that the lead conductor was practically as sound as before charging; the coating of fine peroxide formed on the surface was very thin; there was no sign whatever of buckling, and, further, the specific gravity of the solution, when the cells were left in their then fully charged condition, remained absolutely unaltered.

The conclusion thence drawn was that the oxidisation of the grid caused by charging only penetrated to a very limited depth, and then ceased entirely, and that the coating of fine peroxide formed actually protected the grid, not only from deterioration by overcharging, but also from local action hitherto supposed to be unavoidable.

It was then established that the life of the grids was not proportional to the amount of charging, *i.e.*, to the number of ampère hours *put into* a cell. Was it due to the number taken out? To ascertain this was the object of the next experiment.

For this purpose a battery was divided into two halves, one of which, A, was repeatedly run out, and the other, B, was never discharged beyond the point at which the E.M.F. commenced to drop. This experiment also extended over a considerable time, but gave the instructive result that when exactly the same number of ampère hours had been taken out of each half, the plates in the first half, A, showed signs of expansion or growing, whereas in those of the second half, B, no change could be detected.

The life of the grid then was also not dependent on the *amount* of ampère hours taken out, or on the work done, but on the treatment of the plates, first as to charging up, and afterwards as to total or partial exhaustion. Further, it was satisfactorily proved that there was no necessity to employ a conductor of unoxidisable material, providing the simple precautions were taken:—1st. To fully charge the cells. 2nd. To avoid discharging them entirely.

The second point to be considered is:—2. The buckling of the plates.

This had hitherto been attributed to two or three causes—charging too rapidly; discharging too rapidly; impurities in the acid or oxides employed.

Experiment soon showed that the real cause must be sought for elsewhere.

We found that the buckling was almost invariably accompanied by a hard white enamel (sulphate of lead) on the face of the plates, and further, that where the extra cells in a battery had received more charging than the remainder, the plates in these cells were frequently quite free from sulphate, and the consequent tendency to buckle, while the rest of the battery had failed. This proved that the enamelling could be prevented by charging, and was not due to impurities in the oxides or acid used; further, that when the plates were free from sulphate there was no tendency to buckle.

Experiment also showed that in the case of the first use of cells, when the acid was first put in, the specific gravity dropped in spite of the charging, indicating the formation of sulphate; by persevering in charging the sulphate disappeared, and with it the tendency to buckle. The conclusion was then that in order to avoid buckling of the peroxide plates, cells on their first use (whether new or after long disuse) should be charged incessantly until they are considerably overcharged. Hence the radical change in the instructions issued to users of the E.P.S. batteries. Whereas, hitherto they had been specially cautioned against overcharging, they are now urgently required to overcharge new cells, and to charge incessantly.

3. The separation of the active material. In almost every case where this occurred the plugs of active material fell out of the plates in complete halves and in a very hard condition; and analysis showed that they contained an excess of sulphate, due, as before explained, to insufficient charging. On the other hand, in a few instances the active material was found to have become disintegrated and fallen off in a fine powder, and this was specially observable when on account of a leak in the receiving vessel and consequent frequent addition of water, the solution had become extremely weak. In this case practically no sulphate was present, and the mass lost cohesiveness.

The conclusion is then that a certain proportion of sulphate in the material is necessary to bind it together, but that excess must be avoided. This due proportion once ascertained the third difficulty is overcome for all the ordinary work of secondary batteries.

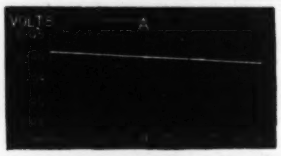
It should be mentioned, however, that there is a constant demand for an accumulator which can be discharged without injury at an abnormal rate for special purposes. Such rapid discharge results at present in the scaling off of the oxides and destruction of the plates, but as it causes the formation of sulphate, which is the binding not the disintegrating agent, the cause of the scaling, and, therefore, its remedy, must be sought elsewhere, and on this point discussion is invited.

I venture briefly to recapitulate the conclusions to which our experiments have led us.

1. That the life of the leaden grids or conductors, and their freedom from buckling, are in no way dependent either on the amount of charging or discharging of the cells.
2. That cells on the occasion of their first use, and also after long intervals of idleness, should be very fully charged, and in the first case incessantly.
3. That they should never, under any circumstances, be entirely run out, and, in fact, should not be discharged below the point at which the E.M.F. begins to drop perceptibly.
4. That the coating of fine peroxide formed during charging is actually a protection to the plate against the injurious effect of over-charging, and against local action.
5. That a certain small proportion of sulphate is necessary to give cohesiveness to the active material, but an excess of it causes the oxide to separate bodily from the conductor.

If the precautions here indicated be taken, we believe that the accumulators now made by the company with which we are connected will answer every ordinary commercial requirement during a very considerable time, but an accumulator is not at present known which, without sacrificing capacity and efficiency, will stand the extraordinary rate of discharge sometimes demanded.

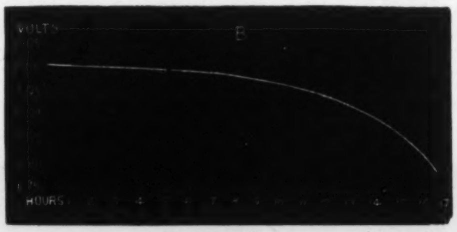
As we thought it might be of interest to give some reliable figures on the results which may be expected from cells as they are now made, we have during the last few weeks, made very careful tests with some cells taken at random from stock and worked in accordance with the practical requirements of an electric light installation.



CURVE A.

It will be seen from the curve marked A, which is the mean of six consecutive discharges, that the E.M.F. is practically constant during a discharge of such duration as the cells would ordinarily be called upon to give, namely, 9 hours—the fall of electromotive force during this period amounting to only ·02 of a volt. When the cells were discharged for 4½ hours, left standing for a day, and then discharged for another 4½ hours, the result was exactly the same as when the discharge was continuous, both as regards E.M.F. and efficiency. In fact, we were able to obtain a short time back from a similar cell, left fully charged for a month, an output of 380 ampère hours.

The charging of the cells under test was always continued for about an hour after the gases commenced to be given off, so as to comply with the requirements of our working instructions, and to keep the plates in good order. This naturally reduced the efficiency or return both in ampère hours and watt hours; but in spite of this over-charging the result of six consecutive charges and discharges gave an efficiency of 90 per cent. ampère hours and 80 per cent. watt hours.



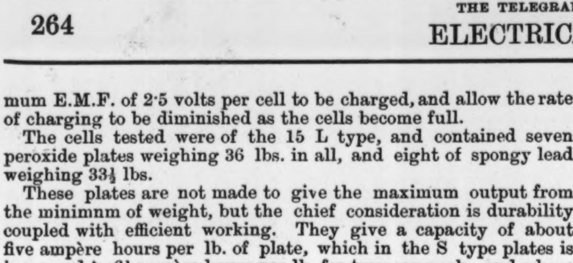
CURVE B.

Curve B shows the capacity of the cells in ampère hours when discharged at 25 ampères rate, and is the mean of two continuous discharges. It will be noticed that with 10 per cent. drop of E.M.F. the capacity is over 400 ampère hours, and that the maximum output given in the lists of the company is reached with a drop of under 5 per cent. in E.M.F.

The curve marked C, shows the rise of E.M.F. during the charge, the current being throughout kept constant at 22 ampères. It will be seen that at the commencement of the charge the E.M.F. required was only 2·02 volts, that after 220 ampère hours had been put in, representing about half the charge, the E.M.F. had risen to 2·13, and that when the cells were giving off gases freely the E.M.F. was as high as 2·53 volts. This curve will no doubt be of interest to those who manufacture dynamos for use with secondary batteries, as it shows clearly the range of E.M.F. for which provision has to be made if the current is to be kept constant. In most instances, however, we arrange for a maximum E.M.F. of 2·5 volts per cell to be charged, and allow the rate of charging to be diminished as the cells become full.

The cells tested were of the 15 L type, and contained seven peroxide plates weighing 36 lbs. in all, and eight of spongy lead weighing 33½ lbs.

These plates are not made to give the maximum output from the minimum of weight, but the chief consideration is durability coupled with efficient working. They give a capacity of about five ampère hours per lb. of plate, which in the S type plates is increased to 6½ ampère hours per lb. for tramcar work; and where durability is of minor importance there no difficulty in obtaining considerably higher results.



CURVE C.

The internal resistance of a single cell was measured during discharge, and found to vary from ·0012 ohm when the cells were fully charged, to ·0026 ohm when discharged, to 10 per cent. drop of E.M.F.

This was tested by observation of the volts, first on open circuit and afterwards discharging at a known rate, but owing to the tendency of the cells to rapidly recover their E.M.F. when left partially discharged, it is somewhat difficult to get reliable results after the E.M.F. has dropped to any extent.

We are convinced that the above figures are absolutely reliable, as the strictest precautions were observed by Mr. Butler, the head of our laboratory, in calibrating the instruments used and checking the results.

The current was measured by frequent readings from a Siemens dynamometer, checked by a voltameter, the two being found to agree within 1 per cent.

The E.M.F. was measured with a reflecting galvanometer calibrated by means of Clarke's standard cells and freshly made Daniell cells, the total resistance of the galvanometer circuit being 40,000 ohms.

PRIMARY BATTERIES.

By A. RENE UPWARD.

(*Read by* MR. C. W. S. CRAWLEY.)

AFTER briefly reviewing the forms of primary battery from the simple elementary cell to those of Daniel, Grove, Bunsen, &c., the author points out that the quantity of current given by the combustion of a given weight of zinc is the same in all batteries, but not the work done by the battery. The E.M.F. is proportional to the net gain of power in the chemical reactions.

The difficulties in the way of obtaining a perfect battery having been recapitulated, the author's battery, the chief characteristics of which are the use of free chlorine gas and the absence of polarisation in consequence of hydrogen not entering into the reactions, was described. The zinc being always in a solution of zinc chloride no local action occurs; there is no fear of mixing of liquids, as only one liquid is used. The further advantages of this form of cell are enumerated as follows:—

No fall in E.M.F., due to the solution becoming weaker, as the outer cells are always full of practically pure chlorine gas; no acids used in the cells (only pure water added); no liquids to remove; absence of smell or fumes; no amalgamation of the zincs; no destruction of the terminals; economy.

The chlorine generator and gasholders were described, as well as the chlorine cell itself, the battery, and the arrangements for the continuous automatic supply of gas to the cells.

DISCUSSION.

Mr. **DESMOND FITZGERALD** said he would like to point out in connection with the sentence in Mr. Crawley's paper, reading "a gas instead of a liquid to act upon the zinc," that it was perfectly understood to all electro-chemists that if chlorine were brought into contact with zinc directly, whether or not there was carbon in the same electrolyte out of contact with the chlorine, the zinc was consumed entirely by local action without any possibility of obtaining a current. Therefore, it was altogether a mistaken idea to suppose that in the Upward battery the chlorine acted directly on the zinc. The ultimate result might be the same as if it did, but the principle to be followed in the construction of the battery undoubtedly was to bring the chlorine into contact with the carbon only, and as far as possible avoid any contact between the chlorine and zinc. To another statement made by his friend and old pupil, Mr. Crawley, he must demur, namely, that chloride of zinc solution had no action upon zinc. Chloride of zinc solution, as a matter of fact had a very powerful action on zinc, a fact which all those who had had occasion to observe the extreme facility with which sub-chloride of zinc and the basic chloride of zinc were formed would be able to emphasise. In regard to Mr. Drake's paper, he could only compliment the E. P. S. Company on the energy and success with which they had overcome the inherent objection to their negative element, which was that it contained the elements of destruction within itself.

Professor **BLYTH** said the storage cell was now so perfect that one felt that the attempt to construct primary batteries for electric lighting to compete with them had but little chance of success. He was very glad, however, to see so good a battery brought forward.

Professor **SILVANUS THOMPSON** said he had made an experiment to test the statements current with reference to the chlorine battery. He took an ordinary cell of glass and placed in it two porous pots side by side. In one of these he placed a stick of zinc and in the other a plate of carbon, and the whole thing was filled up to a certain height with water, with a little chloride of zinc dissolved in it. He thus had a strong solution of chlorine and water. This produced absolutely no effect upon the E.M.F. when poured around the zinc, but raised the E.M.F. to the full value when poured around the carbon. He, therefore, concluded that the chlorine was an excellent depolariser, and that this was its function in the Upward battery. He looked upon Mr. Upward's battery as an extremely ingenious and possibly valuable way of making a constant Leclanché cell, by putting the manganese in a separate generator to evolve the chlorine separately, and then transferring the chemical action from the generator and distributing it through tubes to the respective cells. With respect to the formation of sulphate of lead in the battery which Mr. Drake's paper dealt with, it was pretty clear from the thermo-chemical data, if anyone took the trouble to work out the thermal values of the connections, that the only chemical explanation that could be given of the battery was that the real electrolyte was sulphate of lead, and yet, in spite of that, if they got too much sulphate of lead in the battery, it became almost unworkable. He had made an enquiry into this, and the result he came to was that the sulphate which was disastrous in our batteries was not the ordinary sulphate of lead, but was the basic sulphate, for he had no difficulty at all in reducing, by protracted charging, the ordinary sulphate $PbSO_4$ to spongy lead or to peroxide. But in the case of a battery that had been left partially discharged there was this same sulphate of lead in the presence of a partially deoxidised peroxide, giving rise to a reaction between the lower oxide and the sulphate, and to the formation of the irreducible basic sulphate Pb_2SO_5. The latter was a hopelessly bad conductor. Mr. Drake said his figures, where the efficiency was expressed in ampère hours, were 90 per cent., and the efficiency in watt hours was 80 per cent. There was something curious about this, and he thought the whole thing wanted carefully defining, for he did not think so close an agreement as 80 or 90 per cent. was obtainable, seeing the difference between the E.M.F. and the internal resistance during charge and during discharge.

Mr. **PREECE** said that in practice the resistance of a secondary cell in discharging was very much less than it was in charging. There was a remarkable fact connected with secondary batteries that had not yet received the attention it deserved, namely, that not only was the resistance of a secondary battery cell when being discharged very much less than when it was being charged, but the resistance varied with the current of discharge. The larger the current of discharge the less the resistance, and the result was that a secondary battery was an automatic governor. In lighting up with secondary batteries it had been thought that if the number of lamps was added to, some special contrivance would be needed to make the E.M.F. constant, but owing to this remarkable fact of the varying resistance, the E.M.F. remained practically constant. He could speak with experience of the use of the E.P.S. cells, for he had employed them for the purpose of lighting his house during the whole of the present year. The cells had been greatly improved of late, and they now left nothing to be desired. During the time he had used them he had never observed a flicker or had a disturbance or alteration of any kind, and he attributed that to some extent to the fact that he had implicitly obeyed the instructions given by the company. They did not receive the rough treatment which at one time the E.P.S. Company used themselves to give them. He had seen the company short-circuit a cell and raise a platinum strip a quarter of an inch thick to incandescence. They might anticipate, he thought, that secondary cells would last thoroughly for ten years or more. With regard to primary batteries, the function which the Upward battery was intended to fulfil was rather the function now performed by the gas engine than that of the primary battery. Mr. Upward used a secondary battery to light up a house, but the primary battery kept the secondary battery properly charged. Being in continuous use for 24 hours, the secondary cell was well charged when the time came to light up. He had during thirty years had something like 300,000 primary cells under observation, and therefore could speak of them from experience. He did not look upon primary batteries with any favour for electric lighting purposes. But the Upward battery had started quite a new feature, and was a very promising battery. He did not like the smell of chlorine, but when all difficulty with regard to leakage had been got over he thought there were a great many places (in the country particularly, where gas could not be produced) where this battery would come in very usefully for small installations.

With regard to Professor S. P. Thompson's remarks, the efficiency of a secondary cell was certainly 80 per cent. He had kept an accurate record of current that went into the battery, and the mean of current that came out of it, during the last twelve months, and he certainly got an efficiency out of his cells of 80 per cent.

Prof. Silvanus Thompson said his remarks with reference to the internal resistance of the battery were more particularly in relation to what happened if the same current were used in charging and discharging.

Mr. Henry Lea said he had used, since October or November last, 24 E.P.S. cells for lighting his house, and although the observations had not been taken continuously, as far as he could judge of the action generally of the batteries, Mr. Drake's statements had been borne out. The batteries should be well charged; no harm would be done by overcharging them, and as long as they were frequently overcharged they would preserve their good condition, as far as could be judged from the appearance of the plates.

Mr. R. E. B. Crompton said he regarded a good primary battery as a great desideratum, but he must concur with a previous speaker who pointed out that after all it was only proposed that the primary battery should take the place of the gas engine and dynamo, and must compare with that plant in facility of working and in cost. He was sorry to say that there was such competition in the manufacture of engines and machines that the cost of those parts of an installation was now so small that he did not think Mr. Upward could get below it. He could speak with experience on the subject of accumulators. He had employed them in central station lighting, and was carrying out a large experiment in making accumulators take the place of the gasometer in gas works, for he was convinced that that was the only way in which they could be properly employed in central station lighting. He had been working entirely with the view of getting a certain weight of lead and not a greater number of ampère hours, and greater rapidity of discharge. He had already succeeded in getting a rapidity threefold greater than the company had obtained. Nothing greater than 3 ampères per square foot of peroxide plates had been mentioned, but he had got to 9 or 10 ampères without in the least damaging the cells. That was to say his cells ran down in one-third the time. He thought the reason of this was, that the plates employed were comparatively homogeneous. They consisted of plates of lead cast in a particular manner, becoming porous in the act of casting, and subsequently sawn into thin plates, capable of giving a very heavy discharge indeed without any sign of distortion or any sign of flaking or of the active material being thrown to the bottom of the cell. He attributed the lack of flaking to the homogeneous nature of the plate. When the plate consisted of a grid pasted with a comparatively soft material, under the severe action of a heavy discharge there were distorting actions set up in the plate and a twisting or buckling of portions of the surface. That was perhaps a very crude way of explaining what took place, but he had watched it himself and knew that that was exactly what happened. But when a porous plate was employed consisting of a number of cellular things like a honeycomb, the whole of the interior of the surface being covered with an active material, this throwing down could not take place. The exterior surface was so small in extent that it did not matter. That was one way out of the difficulty of getting rapid discharge from accumulators. He could second what Mr. Preece had said as to the resistance of accumulators. A great portion of the work done in accumulators in the charging was done in the latter part of the charge. What appeared to be resistance mounted up very rapidly; that was probably due to bubbles of gas on the surface of the plate. As everybody wished to charge very fully, they continued to charge until bubbles were formed, and consequently a great deal of work was done on the plate which was never got back as useful work. He would not say that he had got absolutely 80 per cent. from his cells, but he had got very near to it.

Mr. Swan asked whether, in the Upward battery, chlorine produced from hydrochloride of lime had been utilised. It was exceedingly cheap, costing only about £6 or £7 per ton, and it would seem to offer a means of getting chlorine in a very simple manner. After the nauseating repetition of very small changes in the form of primary batteries claiming to be inventions, even if only a change in the form of the vessel from square to round, it was quite refreshing to see some new departure. This battery of Mr. Upward was a new departure in the use of an excess depolariser almost automatically combined. The great difficulty seemed to him to be—and he admired the bravery with which that difficulty had been encountered—to prevent any escape of chlorine. Unfortunately the smallest escape of chlorine—and it seemed impossible to prevent a small escape—would be a quite fatal objection to its use with any comfort in the house, considering how pernicious chlorine was and how it corroded all kinds of metal.

Mr. G. K. Winter spoke of the governing power of the battery in connection with its use for the lighting of trains. Although, of course, the secondary battery put on as a shunt on the dynamo was perfectly able to keep the E.M.F. from rising too high, provided the storage batteries had enough, yet in lighting trains it was of very great importance to get the storage batteries as small as possible, and find some other device to prevent the E.M.F. from rising too high for the safety of the lamps.

Mr. Crawley, in reply to Mr. FitzGerald, said they were well aware of the fact that when Bl was in direct contact with Zn, there was a furious reaction, which was entirely local. But, in point of fact, there was *no* free chlorine whatever in the chlorine cell, for a weighed zinc plate hung up in a cell for days suffered no diminution of weight. Mr. FitzGerald also said that $Zn\,Cl_2$ *should* act on Zn and form sub-chlorides; perhaps it should, but in practice they did not find it do so appreciably. A piece of cleaned raw roof zinc was weighed and found to be 233·2 grains; it was then wrapped round with clean iron wire to promote local action, then placed in $Zn\,Cl_2$ solution taken from a working cell and left for days, at the end of which period it was unwound, well washed and wiped, and weighed 232·9 grains; loss, 0·3 grain. If this sub-action existed, therefore, it was so small as to be completely negligible. The theory which Mr. FitzGerald had shown by means of the blackboard was that which they published some months ago in the pages of the Electrical Review, but which he (Mr. Crawley) omitted in reading the paper, as he had been particularly asked to be as brief as possible. In reply to Prof. Blyth, first, the battery did not compete with secondary batteries; on the contrary, for lighting purposes it was always worked in conjunction with them. 2nd. They had had a battery at work for nine months continuously. 3rd. The resistance of the porous pot did not vary at all; by using pots of proper porosity the zinc chloride solution was kept somewhere between 1·2 and 1·4 sp. gr.; there was no practical variation of resistance, as the specific resistance of $Zn\,Cl_2$ solution was between those rather wide limits practically constant. Professor Thompson had spoken of Cl as the depolariser, which was, perhaps, natural at first sight. But a depolariser implied the existence of H, and as far as he had yet tried, nothing of the action in which H came in could give the E.M.F. which the cell did. On the other hand, the E.M.F. of the cell was practically identical with that due to the direct combination of Zn and Cl. The action took place electrolytically, certainly, and not directly; but if Professor Thompson would look into the action he would find that, nevertheless, the final effect was that the E.M.F. was that due to the direct combination. Mr. Crompton said that the battery could never compete with the dynamo for cheapness. It would in any but what he would consider very small work never attempt to do so. But for such small work as must be done by batteries—and there was a great deal—it was the one which did its work with no waste of zinc, with the very cheapest possible chemicals, and the minimum of attention. In reply to Mr. Swan, they had worked with chloride of lime, but so far without very satisfactory results.

NOTES.

The Electric Light at Hastings.—The contract with the electric light company for the illumination of Hastings Pier expires on January 1st next, and in the meantime the directors are considering the desirability or otherwise of continuing that system. At the annual meeting last week an opinion was expressed that the cost of the electric light was too high, and in response to this the chairman said that they were about to have an interview with the manager of the gas company, when they would be enabled to make a correct calculation. Mr. H. M. Baker (a director of the electric light company and also of the pier company) declared that it would be to the advantage of the former company if the electric light were discontinued on the pier, as the motive power was greatly needed in order to supply other orders. Personally, however he was in favour of the electric light. Ultimately a motion was made to the effect that the electric light should be discontinued on the completion of the present contract. The chairman put the motion, although he stated that the directors were not obliged to act upon it, even though it were carried. Twelve were counted for the motion and eleven against, but just then the chairman's attention was directed to two young ladies who held up their hands against. The motion was consequently declared lost amid laughter and applause.

Electric Lighting in City Offices.—We understand that electric lighting is making rapid strides among the banks, insurance companies, and other large offices in the City. Several London contractors are busily engaged in carrying out work in connection with the above. In most cases accumulators are used, and they seem to give satisfactory results. The installation at the Dock House, Billiter Street, has now been running for some time, and has, we believe, given great satisfaction. This installation was carried out by Messrs. R. E. Crompton & Co., who, we believe, have a number of similar installations in hand for other London companies, banks, &c.

The Electric Light at Bournemouth. — Messrs. Mortimer, Shepherd & Co., electric light contractors, of London, have recently carried out some successful experiments in the Arcade, Bournemouth. In the establishment kept by Mr. Bright a number of incandescent lamps were arranged, while in the centre of the arcade was suspended a large arc lamp. The lamps were connected with wires which communicated with an engine and dynamo situate at the rear of the new Dorsetshire Bank. On the first evening the light was at times a little unsteady, but any manifest imperfections subsequently disappeared, with the result that the first appearance of the electric light in the streets of Bournemouth proved a gratifying and undoubted success.

Foreign Electric Light Companies Dividends.—The results obtained by the Electric Company of Milan appear not to have been by any means as favourable as we (the *Gas World*) were at first led to believe. The *Journal de l'Eclairage au Gaz* reports, after special inquiry, that the dividend was not 4 per cent. but 4 francs per 250 francs, which is 1·6 per cent.; and that for Milan itself the results were:—receipts, £11,040; expenses, £15,480. This is more like the ordinary experience.

The Dalton Lighting Scheme.—The lighting of the streets of Dalton-in-Furness and the streets in the adjacent districts is still giving the Dalton Local Board a considerable amount of trouble. The outlying districts are lighted by oil, but it is said that many of those whom the lamps are supposed to benefit assert that they are "worse than nothing;" Dalton proper is lighted by gas, but the board is of opinion that the price charged by the owners of the gasworks is exhorbitant. Some time ago it was proposed to introduce the electric light in one of the outlying districts, but nothing seems to have come of it. Meanwhile the local board has appointed a committeee to inquire into the relations between the owners of the gasworks and the board, evidently with a view to having the works transferred to the latter.

The Arc Lamp for Ships.—It is well known that electric lighting is by far the best means of illumination for ships, especially those going long voyages. Arc lights, however, have seldom been brought into use for light ship purposes. The Mersey Docks and Harbour Board have, however, decided to use arc lights in one of their light ships lying in the Mersey, and Messrs. Crompton & Co. have been busy for some time fitting in the machinery and lamps. Two or three preliminary trials have already taken place, and we believe the official inspection will shortly be made. We hope that this will be the first of a large number of light ships where the electric light is adopted, as the beams from the arc lamps can be seen very much farther out at sea than from any other illumination.

Progress of Country House Lighting.—Although so little is heard of electric light installations at the present time, we understand that a good many are being carried out, but in most cases in a very private manner. Owners of large houses which are being fitted with the electric light appear of late to be very reluctant to have descriptions published of their residences and how they are fitted up. We know of several cases, the description of which would be very interesting to electrical engineers, but we are debarred from giving these particulars on the above account. There is not the slightest doubt that for large isolated houses, in many cases a long way from towns, electric lighting is by far the best and only means of satisfactorily lighting them up. Such residences as those of Sir John Fowler, at Braemore, N.B., where there happens to be ample water power to drive the machinery; A. P. Vivian, Esq., in Cornwall, and others which Messrs. Crompton & Co. have in hand, could not be satisfactorily lighted by any other means than electricity.

The Electric Light at the Birmingham Art Gallery.—The new electric lighting of the rotunda at the Art Gallery is said to give the fullest satisfaction. The lamps are arranged in a circular frame attached to the structure of the central gas-pendant—an arrangement which has been so carried out as to be no detriment to the architectural features of the gallery; but the new departure is in the introduction of silvered-glass reflectors, scientifically constructed so as to throw the principal portion of the light upon the surrounding walls, while at the same time sufficiently illuminating the floor. An additional and important circumstance in connection with these reflectors is the economy effected, the pictures being better lighted by their employment than if double the number of lamps were employed. This means a saving on account of capital and cost of maintenance of about £500 original outlay and £100 per annum. It should be stated that the arrangement is entirely out of sight by day, while at night attention is not distracted from the pictures by the lighting appliances themselves. The mirror arrangement is entirely new, and the results are such as were not expected by experts in the matter. There is no doubt that the principle will hereafter have a large field for its employment in the lighting of shops, club rooms, and large apartments generally. Mirrors of this kind can, of course, only be used with electric lamps, as gas smoke would at once dim the reflecting surface. The entire installation consists of a nine-horse-power nominal gas engine, of the latest type, and with special arrangements to secure steadiness, a result which is very perfectly attained. This drives a ten-unit Chamberlain and Hookham patent dynamo, specially designed for this installation. With its actual load it has, it is stated, an electrical efficiency of 95 per cent., the armature coils absorbing only 2 per cent. It is absolutely sparkless, and having an automatic brush arrangement, requires little attention. The leads are very heavy, absorbing only 2 per cent of the current which they convey from the dynamo to the lamps.

The Gaiety Theatre.—Messrs. E. L. Berry & Co have received an order to light up the Gaiety Theatre with 180 incandescent lamps three weeks from date of contract.

Progress of the Telephone in Scotland. — An important extension of the system of telephonic communication in Scotland was formally inaugurated at Stirling on Friday by the National Telephone Company, the installation being destined to form a principal link in the connection of the great manufacturing and industrial centres of the East and West of Scotland. Communication between Stirling, Alloa, and Bridge of Allan is completed, and rapid progress is being made with the further work of connecting Stirling with Glasgow and Edinburgh; and so soon as this is completed operations will be commenced with the connection of Glasgow with Dundee *viâ* Stirling, Alloa, Dunfermline, Burntisland, Kirkcaldy, Cupar Fife, and Newport. The switching system employed at Stirling differs considerably from that in Dundee. In the system now in operation there, each subscriber has two wires, one of which is employed for communicating between the subscriber and the operators at the exchange, and the other for communicating betwixt subscriber and subscriber. This system is necessarily a very expensive and complicated one, and the method now employed is one which aims at obviating the necessity for the separate wire between the subscribers and the operators. There was a large and influential attendance at the opening ceremony, most of the principal merchants and manufacturers of the district being present.

Telephonic Communication.—Within the next few days the private residence of Lord Salisbury in Arlington Street will be in direct telephonic communication with the Prime Minister's official residence in Downing Street, special wires having been laid for the purpose. Complete telephonic communication exists between Downing Street and all the Government offices.

Jensen Electric Bell and Signal Company.—The business of this company will henceforth be carried on at Garfield Buildings, Gray's Inn Road, under the management of Mr. H. Jensen.

Sir William Thomson's Improved Rheostat.—With reference to this apparatus, which was described in a paper read before the British Association (see p. 254), we would point out that an instrument somewhat similar in principle was designed by Mr. Groves, and is described in the No. of the REVIEW for June 15th, 1876.

Gas Engines.—The Government have ordered from the British Gas Engine and Engineering Company four 4 H.P. "Differential" gas engines (Atkinson's patent), with patent air compressors combined, to work in connection with "Shone's" system of pneumatic drainage, which is being applied to the Houses of Parliament for dealing with the sewage.

The Electric Light for Lightships.—On and after October 15th, an experiment of an important nature is to be made upon the bar lightship at Liverpool, the Mersey Docks and Harbour Board having decided to exhibit tentatively an electric light instead of the present oil light. The new light is to be visible at a distance of 10 miles, and will show flashes every half minute from sunset to sunrise. Should it be necessary to discontinue the electric light, the oil light will be substituted. After the same date at the same lightship a powerful fog syren will be substituted for the present fog horn.

The Proposed Lighting at Bergen.—We are informed that Mr. J. Meech, of the Thomson-Houston, has been in Bergen, conferring with Mr. Hopstcck on the subject of the central station electric lighting, to which we alluded in our last issue.

A Map of the World.—The Indo-European Telegraph Company, Limited, has issued an admirably got-up map of the world, about 2 feet by 3½. In addition to its being an excellent work of reference, it indicates all the stations of the Indo-European Telegraph Company.

Proposed Electric Tramways for Bergen.—We learn that Mr. F. Wynne, of the Anglo-American Brush Corporation, has been to Bergen for the purpose of securing a 30 years' concession for electric tramways in that town.

Thrashing Corn by Electrical Power.—In addition to those which we have recently recorded, a further application of electric power has just been made on the estate of the Marquis of Salisbury, at Hatfield, by Mr. Shillito, the resident electrician, but in this case Gramme machines have been used; the generator being driven as before by water-power half-a-mile distant. The Gramme machine is connected in the ordinary way to one of Clayton and Shuttleworth's thrashing machines. The result is highly successful in every respect, a very regular, rapid and noiseless power being obtained, in strong contrast with the ordinary steam engine with its demand for skilled attention and for constant supplies of water and fuel. The new motive-power is most promising; and, no doubt, a great saving in cost can ultimately be effected wherever the circumstances for the supply of power are favourable. Should a temporary stoppage of the machine be necessary, an ingenious arrangement has been made by Mr. Shillito, whereby the current from the leads can be turned from the Gramme machine into a cluster of Swan lamps, so that a short break in the operations does not necessitate any communication with the source of power, or stoppage of its regular working, and at the same time it gives warning to the men when the current is running.

Erratum.—In Mr. Moon's article on "The Use of Condensers in Automatic Telegraphy," page 232, in formula 3, for ± 1 read ∓ 1.

Supposed Novelties.—Sir Charles Bright says:—"Why do not inventors study the antecedents of their supposed novelties before hastening to take out patents?" We give it up; but if they did, we fear the Patent Office revenue would look small. Seriously speaking, however, it would be "a boon and a blessing to men" if Patent Office examinations were conducted in this country as in America. There, a person submitting the specification of a supposed invention, is informed whether he has or has not been anticipated.

Industrial Electrical Association.—The following circular has been sent to the principle members of the electrical trades, bearing the signatures of the following companies and firms—W. H. Allen & Co., The Anglo-American Brush Electric Light Corporation (Limited). Goolden & Trotter, The Gülcher Electric Light and Power Company (Limited), R. E. Crompton & Co., Mather & Platt, Paterson & Cooper, Woodhouse and Rawson:—"Several gentlemen connected with the electric lighting trade have long held the opinion that it would be an advantage to form an Industrial Association for the Advancement of the Electrical Industry. The undersigned representing companies and firms closely connected with this subject, think the present a good opportunity to ascertain the feelings of others concerned in the industry on this important matter. We, therefore, enclose a memorandum of the proposed objects to be attained by the formation of such an association, and should be glad if you would write your views on the subject, and if they are favourable, that you will allow us to add your name to our own as adherents. A meeting of the signatories will then be called at an early date to frame rules, appoint an honorary secretary, &c. Kindly address your reply to the Electrical Association, Dynamicable Club Room, 2, Victoria Mansions, Victoria Street, S.W." The memorandum is as follows:—"Industrial Electrical Association.—An industrial association to be formed for the advancement of electrical engineering on a practical basis. The duties of the association being as follows:—1. To facilitate united action with regard to proceedings affecting the trade in Parliament and other public bodies. 2. To hold periodical meetings to discuss prices. 3. To collect and distribute information relating to the trade, its requirements, difficulties, and dangers. 4. To examine and report upon inventions and processes affecting the trade, and the supply and quality of the materials used. 5. To deal with labour questions. 6. If desired, and when requested by the parties to arbitrate on and adjust trade disputes, by competent and recognised authority. 7. To grant certificates of 'Competence in the Art' to individuals."

University College, Dundee.—The foundation of University College, Dundee, may be said to be one of the latest results of that movement for the extension of liberal education and the advancement of technical instruction which has made such rapid progress within the last 10 or 12 years. In Manchester the Victoria University has been developed out of the more modest beginnings of the Owen's College; while at Leeds, Newcastle, Bristol, Sheffield, Birmingham, Nottingham, and Liverpool, local colleges have from time to time sprung up, with the twofold aim of bringing the advantages of higher education within the reach of those who cannot make use of existing University centres, and also of preparing for the degree examinations of such Universities as grant degrees to non-resident students. At the end of the third session of the college which recently closed, Professor Ewing reported as to the Engineering Department, that the number of students had been well maintained, a greater proportion than formerly having taken a systematic course and entered energetically into the work of the classes. In the electrical laboratory a beginning has been made in the direction of original research by Mr. G. C. Cowan, a former student, who is now working with Professor Ewing at a continuation of "Researches in Magnetism," which are being published in the Philosophical Transactions of the Royal Society. During last year the University of St. Andrew's has thrown open its science degrees to students of the college without any condition of residence at the University itself. An impetus has also been given to the work of the college in technical education by the recognition extended to it by the City and Guilds of London Institute. The college is now included in the list of those whose professors are entitled to grant certificates that will be accepted in lieu of those of the Science and Art Department from candidates for the Institute's Full Technological Certificate. There is a great field in Dundee for such operations as those undertaken by the City and Guilds Institute, and Principal Peterson is confident that an increased appreciation of the conditions of technical education, and of the aim of this department of the college work, will gain the support and co-operation of all who wish to see development in this direction. The College Calendar for the fourth session, 1886-7, is just issued, which gives full particulars of the provisions made for the practical teaching of electrical engineering to suit the requirements of students who wish to supplement their general engineering studies with a course of practical and technical electricity, or to make electrical engineering a speciality.

The Society of Engineers.—On Tuesday last the members and associates of the Society of Engineers visited Messrs. Woodhouse and Rawson's Cadby Hall Works, where they were received by Mr. Rawson and by Mr. Allen, the works manager, and Mr. Upward, the electrician. The chief object of interest was Mr. Upward's primary battery.

A Freak of Fortune.—An exchange states that the latest hobby of Mr. Alfred de Cordova, the well-known broker in New York, is that of carrier pigeons. He is at present enjoying a fortune made on "the street," and is leading a luxurious life at his country seat, "Chetolah," near Somerville, N.J. He has instituted a half-hourly despatch by carrier pigeons between his office on Broad Street and Chetolah. The arrival of each bird is signalled by an electric bell in his house, which is connected with the pretty and well-organised pigeon-house.

Personal.—Mr. F. F. Bennett has been appointed district manager for the West Cumberland District of the National Telephone Company, Limited.

Electricity at Southampton Ordnance Survey Offices.—During the visit of Colonials to Southampton Ordnance Survey Offices on Friday, considerable interest was manifested in the electro-typing department. As an engraved copper plate shows some signs of wear after seven or eight hundred impressions have been taken, a facsimile or duplicate of the plate is taken in order to obviate the great expense accruing to re-engraving. To produce this a matrix is electrotyped, and after the process is completed the duplicate can be engraved from with the same accuracy as from the original. For nearly forty years this process has been in use at the offices. Originally the electrical current requisite was obtained from voltaic cells of Smee's pattern, but quite recently these have given place to one of Messrs. Crompton & Co.'s dynamos, driven by a Willans high speed engine. The dynamo is connected to a number of "electrolytic" tanks by means of copper wire leads. The tanks, which contain a solution of sulphate of copper slightly tinged with sulphuric acid, are arranged in "series," so that the electric current passes through each vessel in turn, then through the solenoid of the electrical governor, finally returning to the dynamo. The connections are so arranged that any tank can be cut off from the circuit at pleasure. The use of the tanks was fully explained to the visitors, who were intensely interested in what they saw.

The Polytechnic.—An Industrial Exhibition of work executed by members and students was opened by Sir John Lubbock on Wednesday, the 1st inst., at the Polytechnic Institute, Regent Street, W. Here an attempt is being made to demonstrate practically the various trades taught at the technical classes held during the winter. For this purpose workshops have been erected and fitted with tools, under the gallery of the gymnasium, representing 20 classes. An installation of electric light has been totally undertaken by a committee of students of the electric lighting class connected with the institute, comprising 60 Edison-Swan 16 C.P. lamps run off an Edison dynamo driven by a 12 H.P. Otto gas engine. In the workshops 34 lamps are used, all being fitted with opal shades and hung by flexible wires, the height suited to the requirements of the workers, and two in an aquarium in the gallery. The remainder light the engine room and that devoted to the electrical exhibits. These exhibits comprise the electrical and physical apparatus belonging to the institute, and apparatus kindly lent by Messrs. R. E. Crompton & Co., Woodhouse & Rawson, James Wimshurst, A. P. Lundberg, J. T. Mayfield, J. Orme, and the Electrical Apparatus Company, together with that lent by students of the classes. An arc lamp is also run occasionally from an "A" Gramme machine driven by the same engine. Seven silver medals and eleven bronze, together with £110, are awarded to successful exhibitors. The exhibition remains open until the 10th of September.

The Goolden-Trotter Dynamo.—Messrs. Goolden and Trotter have issued a fourth edition of their descriptive pamphlet, designed to give as much information as possible in a popular form on the subject of electric light, and the appliances connected therewith. On the subject of variable speed, they remark that "one of the greatest drawbacks to the introduction of electric light into mills, factories, &c., has been the necessity of a uniform speed for driving the dynamo. Goolden and Trotter have succeeded in arranging dynamos to run at any required fluctuation of speed, even, say, from 500 to 2,000. Machines of this kind are successfully used for train lighting, being driven from an axle." A description is given of a new regulator which has been devised to meet the want of an apparatus by which the volts of a dynamo may be kept constant where the speed or load is not regular, as in the case of a machine driven off the main shaft of a mill or factory. It can be placed in any convenient position, not necessarily close to the dynamo. Particulars are also furnished of Trotter's patent dioptric system of uniform distribution and diffusion of light. By this means the light can be evenly spread over the illuminated area, producing an effect more nearly resembling diffused daylight than anything else. A room lighted on this principle is equally illuminated throughout, and the sharp shadows usually inseparable from powerful lights are avoided.

The "Volta."—This vessel left the West India Docks on Wednesday on a cruise to Dover; and it is proposed, weather permitting, that this electrically-propelled craft shall make the voyage from Dover to Calais and back to-morrow. Four years have elapsed since the launch *Electricity* made her first trip on the Thames. Several electric boats have during that period been constructed, but the *Volta* is the largest and most complete of the kind, comprising the latest inventions in the application of electricity as a motive power.

Telpherage.—The Telpherage Company writes to say that its line at Glynde is in regular electrical working, but the carrying capacity of the line being in excess of the present requirements of the traffic, the number of trips run is limited. The company will be happy if our correspondent of last week, or others who may be interested, will visit Glynde and inspect the line.

The Telegraph Clerks.—A largely attended and enthusiastic meeting of telegraph clerks has been held at the Foresters' Hall, Clerkenwell. The greatest unanimity prevailed, and resolutions were passed expressing disappointment at the silence of the Government towards their petition, presented in March last, for increased remuneration, and deciding to call the Postmaster-General's attention to the matter. It was also resolved, in the event of no re-arrangement of their postion being forthcoming, to use their best endeavours to draw public and Parliamentary notice to their grievances, official agitation being declared hopeless. Every confidence in the committee was expressed, and a hearty vote of thanks was accorded to Mr. Pickersgill, M.P., for his attitude towards telegraph clerks.

Electric Lighting in the Navy.—In the discussion on navy estimates in the House of Commons on Wednesday, Captain Bethell hoped that the Admiralty would consider the question of electric lighting in ships. The present system of lighting was an element of danger. Lord G. Hamilton said, with regard to electric lighting, we were very much behind in that matter, and he was quite in accord with the observations that had been made as to the necessity and the desirability of introducing electric lighting on board Her Majesty's ships.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

Electric Apparatus Company, Limited.—The annual return of this company, made up to the 1st inst., was filed on the 2nd inst. The nominal capital is £12,000 in £10 shares. 300 shares have been issued as fully paid, and upon 300 shares the full amount has been called and paid. As compared with previous returns, the paid up capital shows an increase of £750. Registered office, 60, Queen Victoria Street, E.C.

National Telephone Company, Limited.—The annual return of this company, made up to the 21st ult., was registered on the 7th inst. The nominal capital is £750,000, divided into 90,000 ordinary shares of £5 each, 15,000 first preference shares of £10 each, and 15,000 second preference shares of £10 each. The whole of the shares are allotted, and the full amount has been called upon the ordinary and first preference shares, and £3 per share upon the second preference. The ordinary shares are considered as fully paid, and the calls received upon the other classes of shares amount to £194,980, leaving £20 unpaid on 20 second preference shares.

Manchester and District Edison Electric Light Company, Limited.—The annual return of this company, made up the 6th inst., was filed on the 7th inst. The nominal capital is £600,000, divided into 50,000 A and and 10,000 B shares of £10 each. 20,000 A and 10,000 B shares have been allotted, and upon the former £2 per share has been called up, and the full amount upon the latter. The total calls paid amount to £140,000. Registered office, 12 (late 19), Victoria Buildings, Manchester.

Telephone Company of Austria, Limited.—The annual return of this company, made up to the 25th August, was filed on the 1st inst. The nominal capital is £200,000 in £5 shares. 13,525 shares have been allotted, and upon 12,485 the full amount has been called, and £1 on 1,040 shares. The calls paid amount to £5,665, and £57,765 is considered as paid upon 11,553 shares. The unpaid calls amount to £35.

Northern District Telephone Company, Limited.—The annual return of this company, made up to the 23rd ult., was registered 4th inst. The nominal capital is £100,000, divided into 15,000 ordinary shares of £5 each, and 2,500 preference shares, the whole of which are taken up and are fully paid; the paid up capital thus showing an increase of £2,639 3s. 8d., as compared with the previous return. Registered office, 13, Exchange Buildings, Quayside, Newcastle-on-Tyne.

TRAFFIC RECEIPTS.

The Cuba Submarine Telegraph Company, Limited. The number of messages passing over the lines of this company during the month of August was 2,848, estimated to produce £2,200, against 2,833 messages, producing £2,262 in the corresponding month of last year. The receipts for the month of May, estimated at £3,050, realised £3,103.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending September 3rd were £2,535 after deducting the fifth of the gross receipts payable to the London Platino-Brazilian Telegraph Company, Limited.

The Great Northern Telegraph Company, Limited. The receipts for August, 1886, were £22,400; from January 1st to 31st August, 1886, £169,960; in the corresponding months, 1885, £192,040; and of 1884, £182,680.

The Direct Spanish Telegraph Company, Limited. The estimated receipts for the month of August, 1886, were £1,370 against £1,326 in the corresponding period of last year.

The West Coast of America Telegraph Company, Limited. The gross earnings for the month ending August 31st, were £3,105.

NEW PATENTS—1886.

10912. "Applying electricity to the human body, &c." S. PITT. (Communicated by H. and W. P. Fairbanks.) Dated August 26.

10926. "Application of volta inductors or secondary generators for distributing electrical energy and for regulating alternate current motors, more particularly applicable to electrical railways." C. D. ABEL. (Communicated by Siemens & Halske.) Dated August 26.

10927. "Administering medical electricity." T. B. GRANT. Dated August 27.

10981. "Electric bells." W. MOSELEY. Dated August 28.

10982. "Electric indicators." W. MOSELEY. Dated August 28.

11001. "Galvanic battery." W. H. BECK. (Communicated by La Société Perreur-Lloyd et Etève.) Dated August 28.

11040. "Secondary battery." E. ANDREOLI. Dated August 30.

11054. "Making and breaking electric circuits. A. THOMPSON, R. O. RITCHIE. Dated August 31. (*Complete.*)

11060. "Electrical apparatus." J. ROOTS. Dated August 31.

11100. "Automatically regulating the amount of electricity flowing to one or more stations." W. C. GOLDNER. Dated August 31.

11101. "Secondary batteries." T. J. JONES, W. H. TASKER. Dated August 31.

11105. "Regulating the electromotive force of a dynamo when driven at different speeds." G. K. WINTER. Dated August 31.

11139. "Glow lamps." C. SEEL. Dated September 1.

11150. "Medico-electrical apparatuses; adjusting devices for use therein, &c." J. R. HARD. Dated September 1. (*Complete.*)

11159. "Secondary batteries or electric accumulators." F. C. HILLS. Dated September 1.

11162. "Controlling electric currents (electrical switch)." W. ROWBOTHAM, F. S. WORSLEY. Dated September 2.

11179. "Applying electricity to spectacle frames." J. T. LEIGHTON. Dated September 2.

11185. "System of electrical distribution." W. C. GOLDNER. Dated September 2.

11194. "Electrical motor escapement for clocks." H. DAVEY. Dated July 19. (*Complete.*)

11214. "Arrangement and constructing of an electric controlling apparatus." C. BONNENBERG, M. KOYEMANN. Dated September 3. (*Complete.*)

11239. "Arrangement of electric battery, with means for regulating the amount of submersion or withdrawal of the negative electrodes." H. CARTER. Dated September 3.

11242. "Effecting the electro-chemical generation of chlorine in metallurgical operations for the extraction of gold from its ores, &c." D. G. FITZGERALD. Dated September 4.

11290. "Automatic printing electro-telegraphic instruments." A. J. BOULT. (Communicated by P. L. Lamure.) Dated September 4.

11291. "Electro-plating." R. K. BOYLE. Dated September 4.

11317. "Electric call and fire alarms." H. J. HADDAN. (Communicated by C. M. Barnes and N. E. Baker.) Dated September 6. (*Complete.*)

11324. "Displaying the electric light on steamships and other vessels." H. BRADLEY. Dated September 6.

11337. "Electrical making and breaking contacts." S. C. C. CURRIE, J. A. TIMMIS.

11355. "Insulating conductors for electrically driven vehicles." O. IMRAY. (Communicated by W. W. Averell.) Dated September 7. (*Complete.*)

11391. "Conduction, distribution, and regulation of electric currents; apparatus employed therein." F. WYNNE. Dated September 7.

11431. "Transmitting messages by magnetism." J. HOLLOWAY. Dated September 8.

ABSTRACTS OF PUBLISHED SPECIFICATIONS, 1885.

8923. "Improvements in apparatus for measuring electric currents." A. G. Brookes. (Communicated from abroad by J. L. Huber, of Hamburg.) Dated July 23. 8d. Claim :—In apparatus for measuring and registering electric currents the combination of a wheelwork, driven by an electric current, with one, two, or more devices, registering either the quantity or the tension, or both the quantity and tension of any circuit of electricity, in such a manner as to mark upon surfaces moved by the wheelwork the positions and motions of the indicator or indicators, caused by the influence of the currents to be measured, substantially as described and illustrated in the drawings.

9325. "Improvements in and relating to regulating devices for electric lamps." W. Lahmeyer. Dated August 4. 11d. Relates to regulating devices for electric arc lamps, in which the expansive power of gases developed by electrolysis is used as the motive power for the regulation. The claims are eight in number.

9601. "Improvements in electro-magnets, and in the application of the same to the control of electric currents." H. W. Ravenshaw. Dated August 12. 8d. The inventor employs a pair of separate electro-magnets and a pair of keepers, or armatures, of which one is in delicate adjustment and the other does the work, and he so arranges them with respect to the electro-magnets that when the current passing around the coils exceeds the desired strength, the keeper in delicate adjustment, or as it may be called the "floating" keeper, is attracted, and by reducing their magnetic resistance, converts the separate electro-magnets into a single horse shoe magnet of greater power than that exerted by the pair of separate magnets. Claims :—1. Constructing together electro-magnets by means of a floating armature, for the purpose of increasing the effective power or pull of the magnets on the working armature, as above set forth. 2. The application of the improved arrangement of electro-magnets to the various uses set forth.

9706. "Improved method of and apparatus for producing induced electric currents." C. D. Abel. (Communicated from abroad by J. C. Pürthner, of Vienna.) Dated August 14. 11d. When induced electric currents are generated by alternately breaking and closing the circuit of a primary source of electrical energy the speed of succession of breakings and closings is limited by the fact that a certain time is required for the magnetisation and demagnetisation of the iron cores, and consequently the primary generator will be utilised half the time only. According to this invention, the possibility of constantly utilising the primary generater is afforded by inserting into the circuit of the said generator, in the manner known as mutiple arc, two primary coils, through which the current is caused to flow alternately, that is to say, every time the shunt of one primary coil is broken, the shunt of the other coil is closed at the same moment. The claims are seven in number.

9762. "Improvements in portable electric lamps." J. E. Liardet. Dated August 17. 8d. Claims :—1. Apparatus for obtaining electric light, consisting of a vase divided at the lower part into battery cells, a cover to these cells to which battery elements are attached, apparatus by which this cover may be lifted within the vase to raise the battery elements out of the cells, and incandescent lamps supported upon the vase or its cover, and suitably connected with the battery elements, substantially as described. 2. Apparatus for obtaining electric light, consisting of a vase divided at the lower part into battery cells; filling and drawing off passages connected with these cells, a plug controlling these passages, battery elements immersed in the cells, and incandescent lamps supported upon the vase or its cover, and suitably connected with the battery elements, substantially as described. 3. Apparatus for obtaining electric light, substantially as described and represented by the drawings.

10180. "Improvements in electrical governors." P. W. Willans. Dated August 27. 8d. Claims :—1. An electrical governor in which a solenoid operates the throttle valve of a steam engine and in which the solenoid core and the throttle valve are enclosed in a casing to which the steam is admitted. 2. An electrical governor in which a solenoid operates the throttle valve of a steam engine and in which the solenoid core and the throttle valve are enclosed in a casing to which the steam is admitted and in which the solenoid is sheltered from the heat of the steam by liquid in which the core is immersed. 3. An electrical governor in which a solenoid operates a valve controlling the flow of a fluid under pressure and in which the solenoid core and the valve are contained in a casing and are alike exposed to the fluid pressure. 4. An electrical governor substantially as described and represented in the drawings.

11056. "Improvements in telephonic transmitters." G. L. Anders. Dated September 17. 8d. Consists in arranging the contacts of the transmitter so that whilst one of them is actuated by the diaphragm the other is held against it in the requisite manner by being imbedded in or attached to a yielding mass of cork or other suitable material, the said mass of yielding material being maintained in its proper place by gravity or by a suitable arrangement of elastic levers, and in cases where gravity is made use of a heavy weight may be pivotted or suspended in any suitable way and the mass of yielding material held in or against or upon the heavy weight or to its support or to any suitable arm or protection attached thereto, but always so that the tendency of the heavy weight to return to its lowest position shall keep the mass of yielding material in or near its neutral position. Claims :—1. A telephonic transmitter constructed or arranged substantially as and for the purpose described. 2. In a telephonic transmitter the combination with a contact carried by the diaphragm of another contact carried in or by a pendulum or weight with the intervention of cork or an equivalent body, substantially as described. 3. A telephonic transmitter wherein one of the contacts is actuated by the diaphragm and the other contact is mounted in or attached to a yielding body of cork or other suitable or equivalent material and maintained in proper normal position relatively to the first contact by gravity elastic levers or equivalent devices substantially as described. 4. The arrangement and combination of parts constituting the telephonic transmitter described and illustrated by the drawings.

11057. "Telephonic transmitting instruments." G. L. Anders. Dated September 17. 8d. Claims :—1. A telephonic transmitter consisting of a number of rods or tubes or the like of carbon lying loosely on or in conducting supports and against each other so that the conducting supports are bridged by the said rods, tubes or the like substantially as described. 2. The constructions of telephonic transmitters described and illustrated in the drawings.

CORRESPONDENCE.

The Regent Primary Battery.

Relative to Mr. Ward's comment upon the prospectus of the company just formed for the promotion of electric lighting by the above battery, it appears to me that the success of this improved form of cell is, as far as domestic utility goes, largely dependent upon the intelligence of our average domestic servant, in which case I think that purchasers of these table lamps will speedily revert to oil and gas, with considerable relief both to mind and pocket.

There are many who will, I think, bear out my assertion, when I say that it is the exception to the rule to find the familiar duplex oil lamp furnishing the light it was intended to do by the makers; either the wicks are badly trimmed or not cut at all, ventilation impeded by congealed oil and dirt, or possibly the reservoir empty, all of which results are due to the negligence and stupidity of our servants; in fact, I know many instances in which the lighting by oil lamps is entirely supervised by the mistress of the house; and yet no process could be easier of management than this; how, then, is this "success of the century" assured as regards the daily illumination of our houses, when corrosive solutions have to be employed, and battery connections, &c., kept clean (as, after all, the *non-fuming* solutions assert themselves very strongly in all exposed parts of a battery, and require close attention in their working) if placed under such trying conditions as I have already referred to.

The problem of domestic electric lighting is, we are told, solved! By that I understand that we are to expect *house lighting* in its entirety with Mary Jane as electrician in charge, in which case I should fancy the cloud of electrical depression arising from the worry and trouble of such awful responsibilities would entirely obscure the occasional glimmer which might possibly occur in the lamps.

The company offer personal supervision of installations where required. What a boon and a blessing to householders to be dependent upon the regular (?) attendance of the company's servants in order to maintain a few lamps in working order, and what imprecations should we not hear from the paternal wrath when the lighting account was rendered.

Having lighted my house for nearly two years with various types of battery, many of really practical design, and in which the labour of working has been reduced to a minimum, I think my remarks concerning the Regent cell will be admittedly consistent by all those who may have had a like experience to mine in the matter of house lighting by electricity.

I have run 20 to 25 8-C.P. lamps for 40 hours with but one charge of solutions, the lighting extending over periods from a week to 10 days, and yet although this particular battery was of most excellent design and easy of manipulation, I should have been very sorry to have handed it over to either my maidservants or to the company's servants for my daily quantum of illumination.

I am but a hungry amateur after electrical science, and as such must apologise for occupying so much valuable space, at any rate, I promise "not to do it again."

Shuntwound.

September 6th, 1886.

Mr. Walker states in his remarks on the Regent battery that "this invention has rendered a practical portable electric miners' lamp possible for the *first time.*" I cannot agree with him in this, for I have for some time past had a portable miners' electric lamp (Schanschieff's), which has been tried in several mines near here, and was afterwards exhibited before the Chesterfield and Midland Counties Institution of Engineers on June 26th, 1886. Date of Schanschieff patent, October, 1885; Maquay (Regent battery), December, 1885. Mr. Swan has also a portable electric miners' lamp.

Geo. Edw. Smith.

4, Cranmer Street, Nottingham.

The Upward Battery.

Absence from home has prevented me from replying to Mr. Upward's letter in your issue of the 20th ult. In the first place, I beg to thank him for his kind invitation to view the battery, and I shall have much pleasure in availing myself of the same at the first possible opportunity. As regards the remark concerning the receiver and regulator, I did not overlook their importance, but I did not think it worth while to go to the trouble and expense of adding them till I saw if the battery would answer the purpose for which I wanted it.

As I stated in the *English Mechanic*, I considered the battery without an equal, subject to the drawbacks which I specified being overcome; and as Mr. Upward states that those defects which I found in my very rough battery are entirely absent from those which are properly made by him, all I can say is, that I consider it without doubt the best battery at present in the market for electric lighting.

J. W. King.

September 7th, 1886.

The facts which I have offered in proof of the theory we hold, and in disproof of that held by Mr. Walker are as follows :—

1st. The E.M.F. which Mr. Walker's theory gives, about 1½ volt, is *not* that obtained in practice, the 2·1 volts, which our theory gives, *is*.

This, though insufficient by itself to absolutely prove our theory, is alone quite enough to disprove Mr. Walker's, but he has never attempted to meet it in any way.

2nd. In the effluent liquid there is a large quantity of $Zn\,Cl_2$, and a mere trace of $H\,Cl$, of which latter there is an external source quite enough to account for it.

Mr. Walker's first theory required $H\,Cl$ to be formed in excess, and his second required equivalent quantities of $Zn\,Cl_2$ and $H\,Cl$.

3rd. Mr. Walker in his last letter brought forward the question of the cell decomposing water, to help him. If any such action takes place it will show up as local action; but the cell has been kept constantly at work for weeks without showing any such action in working tests. If any, then, does take place, which is by no means proved, it must be on such a small scale as to require more delicate tests than we have time to make. At any rate, it has no effect on the main action of the cell, which is the only one before us.

Finally. I only wish for Mr. Upward's sake that Mr. Walker's theory were correct, as in that case we should regenerate hydrochloric acid and make the battery still cheaper than it is.

C. W. S. Crawley.

P.S.—May I ask your readers to compare what I really said on page 100 with Mr. Walker's version of it last week, beginning "2." ?

In Dr. Fleming's report on the Regent battery it is stated that 40 watt hours can be obtained at the cost of 1d., but no particulars are given as to how this cost is arrived at.

Perhaps Dr. Fleming will kindly inform us if it includes the waste of zinc and charge left after the E.M.F. and current have been too much reduced to render the remaining latent energy of any practical value, or if it is based simply on the rate of consumption during the time the cells were working to their best advantage.

There is always a difficulty in arriving at the true merits of a primary cell, and I think a few simple questions properly answered, would be of more value than the quantity of isolated facts generally given.

If, for instance, the following questions were duly replied to, we should be in a position to judge the comparative excellence of any primary cell.

1. *What is the working cost in watt hours per* 1*d.*? The price to include total charge, and the cell to work till either its E.M.F. or current has been reduced by a certain percentage of its original value. (The percentage to be taken at, say, 10 per cent. or any other convenient figure to be agreed upon.)
2. What has been the output in watt hours whilst the cell has been working under the conditions stated above?
3. What are the total number of hours the cell has been working, and what has been the mean current during that time?
4. Has the cell been working continuously, and if not, what were the successive periods of rest and work?
5. What is the ratio between weight of cell and output as above?
6. Are any fumes emitted, and if so, what are they?
7. What is the cost of cell including charge?

N. G. Thompson.

The Calibration of Voltmeters.

I notice that no one has responded to the appeal of "Ajax" regarding the calibration of voltmeters. "Ajax" notices the method of comparison with a known E.M.F.—such as Dr. Fleming's form of the Daniell cell—and remarks :—"It would be of great interest if some one well qualified for the task would kindly explain *ab initio* how with a standard cell of any known E.M.F. one or more galvanometers, a resistance box or bridge, or both, and a variable supply of current (whether from dynamo or battery), the calibration of a voltmeter may be accomplished." I would point out to "Ajax," firstly, the difficulty of doing this clearly in the form of a letter (and in the dog days, too!), and, secondly, would ask him who is better qualified for the task than Dr. Fleming, who very clearly explained—with the advantage of diagrams—such a method of calibration in his paper to the Physical Society (June 27th, 1885). This very able paper was published in the *Philosophical Magazine*, August, 1885, and has been reprinted and circulated in pamphlet form by the Swan Company.

If "Ajax" will obtain a copy of this pamphlet, together with the Swan Company's circular No. 12, he will find all the information he seeks. If he wishes to try his hand at calibration by this method the following facts and suggestions may prove useful :—

My bridge or potentiometer (Dr. Fleming's word) is similar to Dr. Fleming's (pamphlet, fig. 1), but has German silver wire 10 metres long instead of Dr. Fleming's 10 feet; the highest reading I can obtain accurately is about 15 volts. This, of course, can be multiplied in any way "Ajax" may prefer, but if he obtains and preserves on a low-reading voltmeter that is not liable to change a true scale up to 15 volts, I think he will agree with me that he has got something to be thankful for. There is no novelty about the rest of the apparatus. Resistance box Post Office pattern, galvanometer light spot, source of current secondary batteries (I would not advise "Ajax" to try a dynamo as the source unless he is an extremely accomplished "spot watcher"). The arrangement of the various bits of apparatus is fully described in Dr. Fleming's paper. Great care should be observed in getting the specific gravity of the solutions correct, and the cell and rods must be chemically clean. Temperature 15° Cent. The apparatus is extremely sensitive, and the results are, after a little experience in working, accordant.

J. G. Statter.

P.S.—To give an idea of the sensitiveness, the scale along which the movable contact slides, in my instrument, reads about 300 mm. to 1 volt. If you make contact 1 mm. out of place (after plugging the resistance, see Dr. Fleming) your spot sails away gaily! You can read to $\frac{1}{10}$ mm., hence $\frac{1}{3000}$ volt.

[This letter was too late for our last issue.—EDS. ELEC. REV.]

A Simple Make and Break.

I notice in your last issue a description of "a simple make and break switch," in other words, a mercurial switch, believed to be recently patented by a Mr. Raymond Snyers, of Brussels. Enclosed I forward you sketch of a mercurial switch designed by me over two years ago, consisting of a glass or non-conducting tube with platinum wires, one sealed into each end. The tube is half filled with mercury and the air exhausted. The wires of lamp circuit are placed in terminals and are again connected to other terminals, by means of flexible wires, which give according to the action of the tube. When the tube is horizontal as shown in sketch, of course the current is on; when it is vertical the current is off. I fitted several of this class of switch in the New Oak Colliery, Yorkshire, in 1884, and found them to answer very well.

F. F. Bennett.

Whitehaven,
September 3rd, 1886.

[Mr. Bennett's apparatus is precisely similar to that of Mr. Snyers; but still earlier contacts of the same kind have been made, as may be seen by Mr. Giltay's communication. We would also refer Mr. Bennett to a note in our last issue in which, curiously enough, a namesake of his lays claim to an early instrument of the kind, and to the letter of Sir Charles Bright.—EDS. ELEC. REV.]

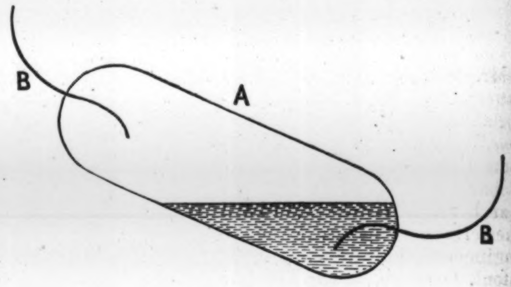
It is astonishing to me how many inventions of the early practical electricians are again and again brought forward and patented now-a-days.

In your number of the 27th ult. you describe and illustrate a recently patented tilting mercurial make and break by Mr. Snyers, of Brussels, and you also refer to a patent of M. Leclanché for the same thing, the specification of which was published in your issue of March 25th, 1882.

If you look at the patent dated March 23rd, 1847, of Mr. W. H. Hatcher (whom I then knew well, as engineer to the Electric Telegraph Company), you will find precisely the same make and break described.

The second claim of his patent relating to the figure appended is as follows :—

"The second improvement relates to the means of forming the metallic connection between wires through which electric currents are transmitted, particularly where such connections have frequently to be made and broken. The sketch, fig. 2, illustrates how this is effected :—A is a tube of glass containing a portion of mercury; after the mercury has been introduced the atmospheric air is expelled, and the tube hermetically sealed, by which the mercury is prevented from becoming oxidated. B, B, are the wires; the openings through which these wires are passed into the tube are hermetically sealed. When the metallic connection is to be formed the tube is brought into the horizontal position, but when broken it is put into that in which it is represented in the figure."



Compare this with the figures and description of the patents of Snyers and of Leclanché.

A fairly-sized book might be compiled showing the many examples of old inventions being re-patented lately, especially in the department of primary batteries, very few of which patents are worth the paper upon which they are written, either from priority of publication or of patent.

Why do not inventors study the antecedents of their supposed novelties before hastening to take out patents?

Charles T. Bright.

31, Golden Square, W.,
September 6th, 1886.

Nothing New Under the Sun.

On page 210 of your last issue you describe a "Simple Make and Break." Allow me to tell you that the same principle was applied by me in 1878 to the construction of a new commutator, the description of which can be found in Wiedemann's Annalen, 1878, Vol. III. The "new" proof of the Wheatstone bridge (page 208 of your same issue) can be found in almost any book on electricity, *f.i.*, in the text books of Fleeming Jenkin and Silv. Thompson, in Cumming's "Introduction to the Theory of Electricity," in "Electricity Treated Experimentally" by the same author, in Gordon's book, &c.

J. W. Giltay.

Delft,
September 1st, 1886.

The Cost of Primary Batteries.

The article in your issue of the 3rd inst. has peculiar interest for me, as I have had to calculate, as far as possible, the cost of electrical energy from primary batteries, but for a different purpose.

I, however, was surprised to see an important factor omitted. I refer to the amount necessary to set aside for interest and depreciation of plant and the cost of supervision and maintenance.

Without these additional particulars, the sums mentioned for chemicals and zinc, &c., appear to me to be almost valueless. It would, I venture to suggest, be of very great interest if these omissions were supplied.

P. Tremain, A.S.T.E

Telegraph Dept. P.O., Plymouth,
September 7th, 1886.

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